NON-WOOD FIBER FOR PAPERMAKING

Rags are as beauties which concealed lie
But when in paper, how it charms the eye!
Pray save your rags, new beauties to discover,
For a paper, truly every one’s lover;
By pen and press such knowledge is displayed
As wouldn’t exist if paper was not made.
Wisdom of things, mysterious, divine,
Illustriously on paper shine.

Boston, News Letter, 1769
Introduction

Wood as a papermaking raw material is a relative newcomer, for nine-tenths of its history, paper was made almost exclusively from non-wood plant fibres. Paper was first made in China in the first century AD. It was produced from old rags, fishing nets, mulberry bark and grass. For the following 1700 years paper was made exclusively from non-wood fibres, such as cotton, hemp, flax and grass. It was 1857 that the process of pulping wood fibres and forming them into a paper web was invented. Wood was quickly established as the primary source of fibre for papermaking and today provides some 90% of the fibrous raw material used in the process. In India and China, two countries which lack forest resources, paper makers turn to their local resources. In India there are about a hundred non-wood pulp mills; in China close to a thousand. [Swayne]

In The Netherlands, traditional raw materials used for paper and board production, virgin wood and recycled paper, are becoming more and more expensive as the paper and board industry have to compete with other stakeholders. By subsidizing the use of wood and paper as a fuel for energy generation (green energy), the Dutch government has introduced more competition in a market in which costs are extremely relevant. Aggravating factor is the increasing international demand on virgin wood and recycled paper. For instance China has a huge need for raw materials in order to provide packages for their export products. It goes without saying that the large demand of China has a worldwide effect on the prices of raw materials.

Every increase in the costs of raw material causes the Dutch paper industry to lose ground internationally. This is why the Dutch Center of Competence Paper and Board\(^1\) has asked us to do a research on alternative fibers to use as a source for papermaking, preferably fibers that can be seen as prepaid\(^2\).

As contradictive as it may seem, China has a long tradition of using alternative raw materials for paper and board production. This is why the KCPK is interested in the possibility of gathering knowledge about the techniques that are used in China.

The following questions were formulated:

- What other raw materials than recycled paper and wood fibres are used in China for paper and board production?
- What alternative materials that are used in China for paper and board productions can be used in the Netherlands as well?
- How does the production process look like to process these fibers into paper?
- What are possible environmental and socio-economical issues?
- What is the availability quality (of qualities) of the produced paper and board?
- Bring back samples if possible
- What are interesting regions to take into account for further investigation?

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1 The Dutch abbreviation is KCPK. We will use this when referring to the Competence Center.
2 Prepaid in this report is used to identify fibers that are residues from other production processes, e.g. food production.
Our investigation consisted of two stages. First we conducted an extensive desk research, using literature, interviews and the internet for collecting as much data as possible. After that, we looked in China for confirmation on the image we had constructed.

You will find the results in this report. In the first part, we will introduce the sorts of raw material – other than recycled paper and virgin wood – that are used in China, with technical remarks about usability, production process issues and quality.

Because of the large potential surface of China, the growing possibilities are nearly without limits. Of course this is definitely not the case in The Netherlands. The second chapter expands further on the possibilities within The Netherlands, focused on climate and logistics.

After that, we will deal with the environmental issues while we end with advice for further exploration.
Words of thanks

We could not have succeeded our investigation without help. In order to do our research, both in The Netherlands and in China, we received a great deal of help of other people. Without the intention of ignoring all people who are not mentioned below, we would like to express our special thanks to:

Weiping Zhang (Georgia Pacific China), who introduced us in the Chinese way of doing business and who helped us with appointments in Shanghai and Beijing;

Mei Huang (Dutch embassy, Beijing), who introduced us to the China Paper Association;

Manxia Jiang and Yulan Zhang (China National Household Paper Industry Association) for providing us necessary backgrounds on the developments around alternative fiber usage and supplying us with (tissue) samples.

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Andrew Gan, Peter MA and Yu Weidong (Kadant China) for backgrounds of (investments in) the Chinese Pulp and Paper Industry.

Anet Bolk and Tjeerd Hobma (TSM) who took care of the logistics of the study trip, so we could concentrate ourselves on our investigation and China itself.

DELTA NV and Georgia Pacific for giving us the opportunity and the necessary time.

Thank you all very much for your co-operation!

Michiel Adriaanse

Harry Morsink

September 2007
Conclusion

Probably being not the desired one, we found an answer to the question what alternative fibers are used in China for paper production. There is a wide range of materials that are used, of which bagasse and straw are the most significant ones. However, the answer to the question is becoming less and less relevant, as the development in China is to close down non-wood fiber plants and investing more and more in largescaled woodpulp facilities because of economical and environmental reasons. This tendency was confirmed during interviews in China, during which we were asked about the progress in environmental solutions when using non-woods. We discovered one exception: a large scaled bagasse pulp factory in the region of Nanjing. Unfortunately, we were not in the opportunity to visit the installation because the plant was flooded at that time.

When not taking into account the developments mentioned above, straw seems to be the most promising non-wood fiber resource. Bagasse simply is not suitable because of climatic reasons. However, the problem with straw – and other non-wood material – is the lack of availability year round. This, combined with the bulkyness of non-woods, creates the necessity to build large stock facilities.

We did not notice the usage of reed canary grass in China, but encountered some reports of this crop during our desk research. This crop is also very promising, given the initiatives already taken in other European countries.

Most of China’s paper and board production is concentrated in Shangdong, Zhejiang, Guangdong, Henan, Jiangsu, Hebei, Fujian, Hunan and Sichuan. These provinces produce about 83% of China’s total. If further investigation is desired, concentrate on these regions, with the most emphasis on Shangdong.

[Hier kan een stuk worden ingevoegd over aandachtspunten m.b.t. het productieproces]

The largest problem is caused by the black liquor and the high silica residu. It is not simple to tackle these problems and the first to solve them has a large advantage. It may be worthwhile to further investigate a plant in Hungary, where part of the fibers are straw, and part is virgin wood, thus creating a less dense black liquor, which can be disposed of relatively easy.

We did not investigate deeply the socio-economical issues of the usage of non-woods. The problems are similar to those of the biofuels and bio-energy production, processes that mostly use the same raw materials as input as the paper industry. Given the added value of biofuels and –energy, the paper industry’s search for non-woods as a solution for the scarcity of wood fibers may be questionable.

Opmerking [gjm1]: Giel, wil jij hier naar kijken?

Opmerking [gjm2]: Wil je deze ook even checken?

Opmerking [gjm3]: Eens? Want is wel gedurfd!
1 ABOUT NON-WOOD FIBRE

On a global scale, non-wood fibres are a minor part of raw material supply to paper and paperboard manufacture. In many countries, however, they are still widely used and are of significant importance in terms of overall volume and as a percentage of total pulp supply.

In this Chapter the following topics will be covered successively:

- Non-wood fibre usage and production
- Characteristics of non-wood fibres
- Categories of Non-wood Fibres
- Advantages and drawbacks of using non-wood fibre for papermaking.

1.1 Non-wood fibre usage and production

The region that has invested the most time and resources into the pulping of non-woods is Asia and the Pacific. In particular, China and India are leaders in the utilization of non-woods for papermaking in terms of volume. In North America, Latin America, Europe, the Russian republics and Africa, the use of non-wood fibre sources has been relatively limited. Table 1 gives an idea of use of non-wood fibres in papermaking in the 18 countries that account for nearly 98 percent of world supply.

Table 1: Leading users of non-wood fibres in papermaking [Pande]

<table>
<thead>
<tr>
<th>Country</th>
<th>1993 Non-wood pulping capacity ('000 tonnes)</th>
<th>1998 (estimate) Non-wood pulping capacity ('000 tonnes)</th>
<th>Percentage of total pulping capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>15246</td>
<td>16830</td>
<td>86.9</td>
</tr>
<tr>
<td>India</td>
<td>1307</td>
<td>2001</td>
<td>55.5</td>
</tr>
<tr>
<td>Pakistan</td>
<td>415</td>
<td>415</td>
<td>100.0</td>
</tr>
<tr>
<td>Mexico</td>
<td>321</td>
<td>324</td>
<td>29.2</td>
</tr>
<tr>
<td>Peru</td>
<td>298</td>
<td>296</td>
<td>95.2</td>
</tr>
<tr>
<td>Indonesia</td>
<td>267</td>
<td>267</td>
<td>22.1</td>
</tr>
<tr>
<td>Colombia</td>
<td>218</td>
<td>218</td>
<td>45.1</td>
</tr>
<tr>
<td>Thailand</td>
<td>209</td>
<td>509</td>
<td>100.0</td>
</tr>
<tr>
<td>Brazil</td>
<td>196</td>
<td>238</td>
<td>3.1</td>
</tr>
<tr>
<td>Venezuela</td>
<td>185</td>
<td>187</td>
<td>75.2</td>
</tr>
<tr>
<td>United States</td>
<td>179</td>
<td>204</td>
<td>0.3</td>
</tr>
<tr>
<td>Greece</td>
<td>150</td>
<td>160</td>
<td>85.7</td>
</tr>
<tr>
<td>Spain</td>
<td>140</td>
<td>141</td>
<td>7.9</td>
</tr>
</tbody>
</table>
At the present time, the most commonly utilized non-wood fibre is straw, which accounts for 46 percent of total production (see Table 2). This is followed by bagasse (14 percent) and bamboo (6 percent). Other non-wood fibres such as cotton, hemp, sisal and kenaf are also becoming more important in the manufacture of pulp and paper.

Table 2: Leading non-wood fibres for Paper production worldwide [Pande]

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Non-wood papermaking pulp capacities (kton)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1985</td>
</tr>
<tr>
<td>Straw</td>
<td>6166</td>
</tr>
<tr>
<td>Bagasse</td>
<td>2339</td>
</tr>
<tr>
<td>Bamboo</td>
<td>1545</td>
</tr>
<tr>
<td>Miscellaneous: cotton, reeds, sisal, jute, hemp, abaca, kenaf, flax</td>
<td>3302</td>
</tr>
<tr>
<td>Total</td>
<td>13352</td>
</tr>
</tbody>
</table>

In figure 1 and 2 the following parameters are showed:
- Non-wood pulping capacity (as percent of world total) [Kinsella]
- Estimated non-wood pulping capacity (percent of total country’s total pulping capacity) [Kinsella]
Figure 1: Non-wood pulping capacity (as percent of world total) [Kinsella]

Figure 2: Estimated non-wood pulping capacity (percent of total country's total pulping capacity) [Kinsella]
Utilization of non-wood fibres for the paper industry continues to grow only in countries where:
- On the one hand wood resources are limited and
- While annual plants are available in relevant quantity.

1.2 Characteristics of non-wood fibres

1.2.1 Fibre dimensions of non-wood plant fibres

The average dimensions of various non-wood plant pulp fibres as compared with dimensions of wood pulp fibres are listed in Table 3. The data show the wide variation in the fibre characteristics of non-wood fibres. Many of the non-wood fibres are similar to the short fibre hardwoods, while others are so long that they must be shortened to optimize their papermaking value. In general, the diameter of the non-wood fibre is small, resulting in lower coarseness from these pulps. These fibre dimensions provide an idea of the potential usefulness of these pulps in pulp and papermaking. In fact, from the technical and quality viewpoints, any grade of paper can be produced by using the appropriate combination of non-wood plant fibres (eventually mixed with wood fibres).

Table 3: Non-wood plant fibre raw material [Pande and Hurter]

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Fibre length [mm]</th>
<th>Fibre diameter [microns]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Straw &amp; stalk fibres</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cereal straw</td>
<td></td>
<td>1.5</td>
<td>23</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>Triticum aestivum</td>
<td>1.0-1.5</td>
<td>13</td>
</tr>
<tr>
<td>Corn straw</td>
<td></td>
<td>1.0-1.5</td>
<td>18</td>
</tr>
<tr>
<td>Rye straw</td>
<td>Secale cereale</td>
<td>1.5</td>
<td>13</td>
</tr>
<tr>
<td>Oat straw</td>
<td>Avena sativa</td>
<td>1.5</td>
<td>13</td>
</tr>
<tr>
<td>Barley straw</td>
<td>Hordeum vulgare</td>
<td>1.5</td>
<td>13</td>
</tr>
<tr>
<td>Rice straw</td>
<td>Oryza sativa</td>
<td>0.5-1.4</td>
<td>8-10</td>
</tr>
<tr>
<td>Corn stalk</td>
<td>Zea mays</td>
<td>1.0-1.5</td>
<td>16-20</td>
</tr>
<tr>
<td>Sorghum stalk</td>
<td>Andopogon bicolor</td>
<td>1.0-1.7</td>
<td>20-47</td>
</tr>
<tr>
<td>Common name</td>
<td>Scientific name</td>
<td>Fibre length [mm]</td>
<td>Fibre diameter [microns]</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------------</td>
<td>-------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Cotton stalk</td>
<td><em>Gossypium hirsutum</em></td>
<td>0.6-0.9</td>
<td>20-30</td>
</tr>
<tr>
<td><strong>Reed &amp; grass fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common reed</td>
<td><em>Phragmites communis</em></td>
<td>1.5-2.5</td>
<td>20</td>
</tr>
<tr>
<td>Giant reed</td>
<td><em>Arundo donax</em></td>
<td>1.2</td>
<td>15</td>
</tr>
<tr>
<td>Papyrus</td>
<td><em>Cyperus papyrus</em></td>
<td>1.5</td>
<td>12</td>
</tr>
<tr>
<td>Reed canary grass</td>
<td><em>Phalaris arundinacea</em></td>
<td>1.0</td>
<td>20</td>
</tr>
<tr>
<td>Elephant grass</td>
<td><em>Miscanthus sinensis</em></td>
<td>1.2</td>
<td>20</td>
</tr>
<tr>
<td>Esparto</td>
<td><em>Stipa tenacissima</em></td>
<td>1.1-1.5</td>
<td>9-12</td>
</tr>
<tr>
<td>Sabai</td>
<td><em>Eulaliopsis binata</em></td>
<td>2.1</td>
<td>9</td>
</tr>
<tr>
<td>Switch grass</td>
<td><em>Panicum virgatum</em></td>
<td>1.4</td>
<td>13</td>
</tr>
<tr>
<td><strong>Cane fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bagasse / Sugarcane</td>
<td><em>Saccharum officinarum</em></td>
<td>1.0-1.7</td>
<td>20</td>
</tr>
<tr>
<td>Bamboo</td>
<td></td>
<td>2.7-4</td>
<td>15</td>
</tr>
<tr>
<td><strong>Bast fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flax</td>
<td><em>Linum usitatissimum</em></td>
<td>25-30</td>
<td>20-22</td>
</tr>
<tr>
<td>Hemp</td>
<td><em>Cannabis sativa</em></td>
<td>20</td>
<td>22</td>
</tr>
<tr>
<td>Sun hemp</td>
<td><em>Crotalaria juncea</em></td>
<td>2.5-3.7</td>
<td>25</td>
</tr>
<tr>
<td>Kenaf</td>
<td><em>Hibiscus cannabinus</em></td>
<td>2.6</td>
<td>20</td>
</tr>
<tr>
<td>Jute</td>
<td><em>Corchorus capsularis</em></td>
<td>2.0-2.5</td>
<td>20</td>
</tr>
<tr>
<td><strong>Core fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kenaf</td>
<td><em>Hibiscus cannabinus</em></td>
<td>0.6</td>
<td>30</td>
</tr>
<tr>
<td>Common name</td>
<td>Scientific name</td>
<td>Fibre length [mm]</td>
<td>Fibre diameter [microns]</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------</td>
<td>-------------------</td>
<td>-------------------------</td>
</tr>
<tr>
<td><strong>Leaf fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abaca / Manilla hemp</td>
<td><em>Musa textilis</em></td>
<td>6.0</td>
<td>20-24</td>
</tr>
<tr>
<td>Sisal</td>
<td><em>Agave sisalana</em></td>
<td>3.0-3.5</td>
<td>17-20</td>
</tr>
<tr>
<td><strong>Seed hull fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cotton staple</td>
<td><em>Cossypium hirsutum</em></td>
<td>20-30</td>
<td>20</td>
</tr>
<tr>
<td>Cotton linters</td>
<td><em>Cossypium hirsutum</em></td>
<td>0.6-3.0</td>
<td>20</td>
</tr>
<tr>
<td>EFB (oil palm empty fruit bunch)</td>
<td><em>Elaeis guineensis</em></td>
<td>1.0</td>
<td>20</td>
</tr>
<tr>
<td><strong>Tree-based fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Softwood (coniferous)</td>
<td></td>
<td>2.7-5.0</td>
<td>32-43</td>
</tr>
<tr>
<td>Hardwood (deciduous)</td>
<td></td>
<td>0.7-3.0</td>
<td>20-40</td>
</tr>
<tr>
<td>Eucaluptus</td>
<td></td>
<td>0.7-1.3</td>
<td>20-30</td>
</tr>
</tbody>
</table>
### 1.2.2 Chemical Properties of various Non-woods

In the next table some chemical properties of various non-woods are given.

**Table 4: Non-wood plant fibre raw material [Kinsella]**

<table>
<thead>
<tr>
<th>Fibre/Source</th>
<th>Cellulose (%)</th>
<th>Lignin (%)</th>
<th>Pentosans (%)</th>
<th>Ash (%)</th>
<th>Silica (%)</th>
<th>Pulp yield (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jute</td>
<td>57</td>
<td>16-26</td>
<td>15-26</td>
<td>0,5-2,9</td>
<td>&lt; 1</td>
<td>42</td>
</tr>
<tr>
<td>Kenaf</td>
<td>53</td>
<td>15-18</td>
<td>21-23</td>
<td>2-5</td>
<td>4</td>
<td>46</td>
</tr>
<tr>
<td>Flax</td>
<td>70</td>
<td>10-25</td>
<td>6-17</td>
<td>2-5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abaca</td>
<td>61</td>
<td>9</td>
<td>17</td>
<td>1</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>Sisal</td>
<td>43-56</td>
<td>8-9</td>
<td>21-24</td>
<td>0.6-1</td>
<td></td>
<td>&lt;1</td>
</tr>
<tr>
<td>Cotton</td>
<td>80-90</td>
<td>3-3,5</td>
<td></td>
<td>1-1,2</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>Bagasse</td>
<td>55</td>
<td>18-24</td>
<td>27-32</td>
<td>1,5-5</td>
<td>0,7-3</td>
<td>45-65</td>
</tr>
<tr>
<td>Bamboo</td>
<td>52-68</td>
<td>21-31</td>
<td>15-26</td>
<td>1,7-5</td>
<td>1,3-3</td>
<td>38-45</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>16-21</td>
<td>26-32</td>
<td>2,5-10</td>
<td>3-7</td>
<td></td>
<td>39-62</td>
</tr>
<tr>
<td>Esparto</td>
<td>17-19</td>
<td>27-32</td>
<td>6-8</td>
<td>2-3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reed</td>
<td>22</td>
<td>20</td>
<td>3-4</td>
<td>2</td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>Soft wood</td>
<td>57</td>
<td>26-34</td>
<td>7-29</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>45-70</td>
</tr>
<tr>
<td>Hard wood</td>
<td>23-30</td>
<td>19-26</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td></td>
<td>45-70</td>
</tr>
</tbody>
</table>

**Remarks:**

- The presence of silica is the way that the plant is protecting itself from the environment. Trees use bark for protection while annual plants have high silica content, which acts as a ‘skin’ for the plant. [Andtbacka]
- High pentosan levels increased black liquor viscosity.
1.3 Categories of Non wood Fibres

There are four types of different categories of sources for the non-wood fibres (sometimes compacted to three).

- **‘On-purpose’, or dedicated, crops** grown specifically for paper fibre; such as hemp, kenaf, jute, flax and bamboo.
- **Agricultural residues** (sometimes called Field or harvesting residues) are materials left in an agricultural field or orchard after the crop has been harvested. These residues include straw, stalks (corn, sorghum, cotton). It is renewable in real time, while the fastest renewal time for commercial pulpwod is seven years. The cost of such plant fibre has already been "pre-paid" by the production of grain and oilseeds. Existing farm machinery can be used. [Wong] Crop residues can be used as animal fodder, bedding, soil amendment and as energy source. Agricultural by-products are characterized by a low raw material price and moderate quality. [Finell]
- **Industrial residues** (sometimes included with agricultural residues and called ‘process residues’) are those materials left after the processing of the crop into a usable resource. The wastes after agricultural products are processed are called Agricultural Processing Residues. They include bagasse, hemp residue, rice husk and peanut crust, cotton linters snipped from cottonseed after ginning for textiles but before pressing for oils; cotton or linen scraps from clothing production, flax residue from oilseed. It is easy to collect and transport this type of raw material because it is already mainly stocked in the factories. High quality pulp can be produced from industrial crops, but the raw material is more expensive; however, the raw material costs of natural plants are competitive with wood. [Finell]
- **Naturally occurring uncultivated crops** (natural stands) such as wild grasses, sisal, reeds, papyrus and bamboo. [Kinsella]

Agricultural residues account for 73% of the world’s non-wood pulp capacity, natural plants such as reed and bamboo account for 18%, and the remainder consists mainly of industrial crops. [Finell]

Another kind of classification can be made based on substitutes:

- **Hardwood substitutes** or common non-woods such as cereal straws, bagasse, bamboo, reeds and grasses, esparto, kenaf, corn stalks, sorghum stalks etc.
- **Softwood substitutes** or specialty non-woods such as cotton staple and linters; flax, hemp and kenaf bast fibres, sisal, abaca, bamboo etc.

In combination with fibre length the following matrix appears.

<table>
<thead>
<tr>
<th></th>
<th>Agricultural residues</th>
<th>Industrial residues</th>
<th>Naturally occurring plants</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Long fibres</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- flax</td>
<td>- hemp</td>
<td>- sabai</td>
</tr>
<tr>
<td></td>
<td>- jute (bast)</td>
<td>- abaca</td>
<td>- bamboo</td>
</tr>
<tr>
<td></td>
<td>- kenaf (bast)</td>
<td>- cotton linters</td>
<td>- sisal</td>
</tr>
<tr>
<td><strong>Short fibres</strong></td>
<td>- cereal straw</td>
<td>- kenaf (core)</td>
<td>- esparto</td>
</tr>
<tr>
<td></td>
<td>- rice straw</td>
<td>- jute (core)</td>
<td>- bamboo</td>
</tr>
<tr>
<td></td>
<td>- bagasse</td>
<td>- coconut husks</td>
<td>- reeds</td>
</tr>
<tr>
<td></td>
<td>- corn stalks</td>
<td>- oil palm bunches</td>
<td></td>
</tr>
</tbody>
</table>
1.4 Advantages and drawbacks of using non-wood fibre compared to wood fibre
Throughout the cycle, from cultivation to use, fibres derived from non-wood plants differ from those derived from wood.

1.4.1 Advantages

Cultivation and harvesting of non-food crops is favourable compared to wood fibre in several ways:
- The payback time of non-wood plantations is much shorter than that of forest plantations, because harvesting of non-woods can start already after few months from sowing.
- Perennial crops: multiple harvests from one plantation.
- Non-wood plantations consume less water and fertilizers.
- Equipment for sowing, harvesting and baling is already available at farms.
- Ready infrastructure and no special vehicles required for transportation.
- Producing paper from non-wood fibres would help in reducing the need to procure pulpwood from natural forests, and for large-scale plantations. [Pande]
- The use of non-wood materials can reduce deforestation in some countries and
- Reduce emissions of carbon monoxide and carbon dioxide that arise from the burning of waste agricultural residues.
- It can have a positive effect on employment and social structure in sparsely populated areas. [Finell]
- Some non-wood fibres used as raw materials for papermaking have high annual yields per hectare. See for yield numbers of several non wood crops, table 6.

Table 6: Average annual yields of different papermaking raw materials [Pande]

<table>
<thead>
<tr>
<th>Plant</th>
<th>Fibre yield (tonnes/year/ha)</th>
<th>Pulp yield (tonnes/year/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scandinavian softwood</td>
<td>1.5</td>
<td>0.7</td>
</tr>
<tr>
<td>Fast-growing softwood</td>
<td>8.6</td>
<td>4</td>
</tr>
<tr>
<td>Temperate softwood</td>
<td>3.4</td>
<td>1.7</td>
</tr>
<tr>
<td>Fast-growing hardwood</td>
<td>15</td>
<td>7.4</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>4</td>
<td>1.9</td>
</tr>
<tr>
<td>Rice straw</td>
<td>3</td>
<td>1.2</td>
</tr>
<tr>
<td>Bagasse</td>
<td>9</td>
<td>4.2</td>
</tr>
<tr>
<td>Bamboo</td>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>Kenaf</td>
<td>15</td>
<td>6.5</td>
</tr>
<tr>
<td>Hemp</td>
<td>15</td>
<td>6.7</td>
</tr>
<tr>
<td>Elephant grass</td>
<td>12</td>
<td>5.7</td>
</tr>
<tr>
<td>Canary grass</td>
<td>8</td>
<td>4.0</td>
</tr>
</tbody>
</table>
**Processing (Pulping)** of non-wood materials is favourable compared to wood fibre in several ways:
- Neither chipping nor debarking is required.
- The majority of the non-wood fibrous raw materials have considerably less lignin than the wood materials. This means that most non-wood materials can be pulped with simple chemical systems such as caustic soda. The alkali charge required for a non-wood fibrous raw material is normally lower than what is required for wood based raw materials to achieve the same degree of delignification. [Finell]
- Easy and uniform impregnation of cooking chemicals thanks to thin structure.
- No shives.
- It is found that most non-wood fibres require less refining energy to achieve the same freeness crops as in wood pulps.
- Bleaching non-wood fibres is easier than wood fibres. Most non-woods can be bleached to high brightness in short bleach sequences and using lower chemical charges. [Hurter; 1998]
- Pulping non-wood fibres requires less energy than wood fibres.

### 1.4.2 Disadvantages

**Cultivation and harvesting** of non-wood crops is non-favourable compared to wood fibre in several ways:
- Competing uses for waste organic materials [Chempolis]
- The availability of a constant, year-round supply of fibre is a primary concern for paper mills. Given that most non-woods are annual plants, the crops have short harvesting seasons; requiring storage of the harvested crop over a number of months, [Hunt]
- The storage conditions and moisture content of straw are important because it is susceptible to moulds and rot, and subject to spontaneous combustion. Weathered straw consumes more chemicals for pulping and yields less pulp of relatively lower strength. [Rymsza]
- The recovery of agricultural residues also may not be economical. Their production is widely distributed in areas where the transport infrastructure may not be well developed and where communications to support the organization of collection are poor. This limits the supply radius for a straw based pulp mill considerably. Also, the bales are bulky and are more difficult to handle than wood chips. [fiberfutures]
- The agricultural residues are a by-product of food/feed production and not harvested in optimal conditions for fibre production, thereby giving a lower pulp yield. [Finell]
- Collection, transportation and storage of agricultural residues call for special attention, and the cost of transport and storage is high due to the bulky nature (most non-wood fibre sources are high in volume and low in density when compared with wood) which dictates local processing. A large storage capacity must be developed to support continuous pulp production, exposing the crop to decay if not properly preserved. [Tutus] Compacting technology is there but still needs energy to compact them. A paper mill needs to be within 100 km of the supply to make the fibre affordable. But small regional pulping mills could not compete with large wood pulping mills. [Jong; Sadawarte]
- The ash content of non-wood plants varies between 1% and 20%. Whereas in softwoods and hardwoods the same value is generally less than 1%. [Tutus]
- The fibre length of non-woods is generally shorter, which limits the range of paper qualities that can be produced. [Sadawarte]
- Cereal straw is also highly dependent on agricultural subsidies thus making a long-term availability unreliable, especially in the Nordic countries. [Finell]
Non-wood crops are characterized by variations in plant size and composition due to variations in cultivation conditions (these crops are more susceptible than trees to abnormalities in seasonal weather patterns such as floods and droughts, climate, soil) and variations in storage time (from a few days old to a few years old at the pulp mill). This variation needs strict quality control, and means a supplier has a higher risk that bales will be rejected than in case of a wood fibre supply; however, with proper quality control, this variation can be managed. [Fiberfutures]

Processing (Pulping) of non-wood materials is non-favourable compared to wood fibre in several ways:
- Because of the low density of the crops, they need more pulping liquid [Hunt] and need more volumes in process equipment.
- High pollution levels associated with current, low-technology production methods. Pollution from non-wood fibre mills can be up to 20 times that from wood pulp mills and could prove an inhibiting factor in this sector. [Chempolis]
- For the most part, non-wood raw materials contain higher amounts of silica than woods. During pulping, the silica is dissolved and enters the black liquor. High silica content in the black liquor results in various problems in the chemical recovery loop, including:
  - Increased black liquor viscosity at high solids concentrations (due to the presence of high pentosan levels), which make it difficult to impossible to pump the black liquor at some parts of the recovery process.
  - Hard scales in the evaporator and hard deposits as various points in the recovery boiler which reduces the efficiency of some equipment and actually can plug it
  - Formation of colloidal gels in the recausticizing system that lower the settling rate.
  - Formation of glassy material in the lime kilns.
  - Reduced slacking rate.
  These problems make chemical recovery difficult, less efficient and more costly as compared to recovery for black liquor from wood. Without recovery a pulping process is extremely polluting which explains why there is lots of straw pulping in China, but not in the US. Therefore, as much silicon must be removed from the recovery cycle as gets into the process with the raw material. The investment cost of such silica removal system is only a few percentages of the whole mill investment. [Hurter 1998; fiberfutures, Paavilainen]
- Due to the high water retention capacity of non-wood fibres (especially straw), each separation step requires about three times as much separation capacity as for hardwood processing. This means a significant increase in capital investment per ton of straw pulp versus hardwood pulp.

Papermaking
- The large amount of fines (which are also less coarse than fines of wood fibre) and the shorter fibre length affect especially the drainage properties of pulp. Slow draining requires either a reduction in processing speed or a lengthening of the drying section, which significantly increases processing (and energy) costs. [Jong, Paavilainen, Rousu]
<table>
<thead>
<tr>
<th>Fibre</th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Technologies</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bagasse</td>
<td>Short grow time</td>
<td>Requires depithing.</td>
<td>Well developed pulp technologies available</td>
<td>Most paper types</td>
</tr>
<tr>
<td></td>
<td>1 year rotation.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste fibre source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemp</td>
<td>Rapid growth 8-10 ft in four months</td>
<td>Requires decortication and retting. Perceptual problem due to drug association. Long fibre wraps round equipment.</td>
<td>Well-developed pulp technologies available. Drug free variety available.</td>
<td>Cigarette paper, strength additive to waste paper, light weight papers</td>
</tr>
<tr>
<td>Kenaf</td>
<td>High yield 21.3 mt/ha in 3 years.</td>
<td>Dual source: 57% long bast fibre, 41% short core fibre, therefore bark and core separation required.</td>
<td>Excellent papers have been made using existing technology.</td>
<td>Wide range due to variety of fibres.</td>
</tr>
<tr>
<td>Wheat straw</td>
<td>Short grow time</td>
<td>Problems with black liquor treatment. Perceptual problems</td>
<td>Well-developed pulp technologies available. Successful work on black liquor done.</td>
<td>Most paper types</td>
</tr>
<tr>
<td></td>
<td>1 year rotation.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste fibre source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linseed Flex</td>
<td>Byproduct of linseed industry. Low cooking and TMP refining energy. Similar cost to hard wood in Canada ($60/ton)</td>
<td>Needs decortication before cooking. Lower brightness than wood after TMP</td>
<td>Well documented as beneficial in blends with wood pulps. Processing technology is understood.</td>
<td>Used in wood pulp blends to improve strength.</td>
</tr>
</tbody>
</table>

1.4.3 Environmental drawbacks

Non-wood fibre mills have become serious polluters, and their prospects for survival and expansion are small. In addition to the loss of pulping chemicals in black liquor, there is a huge national waste of electricity in manufacturing the chemicals. Environmental consciousness all over the world will force countries to fall in line and impose stringent pollution control laws which will probably force the small mills to either stop pulping agricultural residues and change over to wastepaper, or increase pulping capacity to make recovery viable. [Sadawarte]
In China, the paper industry is still challenged by pollution. According to the State Environmental Protection Administration, the amount of COD discharged by the paper industry accounts for about one-third of the total by all the industries of the country for 2004, of which over 60% by straw pulping. [Poyry nr 2]

The single biggest technical problem that has so far eluded solution by small pulp and paper mills in China and India, is the absence of a dependable and economic chemical recovery system. What the industry is looking for is the installation of a 100 ton/day demonstration plant. All the wood-based 100 to 200 ton/day mills have conventional chemical recovery systems. However, 15 to 30 ton/day mills using agricultural residues do not. The loads of suspended solids, biological oxygen demand (BOD) and chemical oxygen demand (COD) are about six times higher, and color is about 10 times darker, than at a wood-based mill with chemical recovery.

The last straw pulp mills in the Western world all closed during the last decade: Dunavarosc in Hungary (1980's), Fredericia in Denmark (1991), and SAICA in Spain (1999). And, they all closed for the same reason - they could not comply with tightening environmental regulations. [fiberfutures]

This is in contradiction with information received from Metso. They have a full straw pulping line running in Hungary, which can be visited as a reference.

One can find various new environmental friendly processes for non-wood pulping (Conox; Siloxy; Chempolis; Free Fiber). Surprisingly enough non of the institutes or experts spoken with in China was aware of them. This probably comes back to the fact that suppliers not having references of these systems on a full scale. Besides that, it's also likely once China is aware of them that they don't choose for these new developments simply because they're far to expensive compared to local designs.
2 ABOUT CHINA; PAPER USE; NWF USE ETC

China, the cradle of papermaking. In 104 AD, the first paper was made from a mixture of bark, flax and old fishing nets. In 2003, non-wood pulp consumption rose 5.41% to 11.70 million metric tons but dropped by 2% to 30% in the total fibre consumption.

China’s non-wood pulp and paper industry is under threat in recent years because of the damage non-wood fibre mills cause to the environment. At the moment China imports most of it’s wood fibre due to the lack of domestic sources. But the country has abundant and underutilized non-wood fibre resources including straw, reed, bamboo and bagasse. The available straw alone would be sufficient to eliminate all fibre imports. Although non-wood pulp and paper represents 60% of pollution caused by China’s pulp and paper sector today, it is also an important source of employment, sustaining the livelihood of some 8 million people. [IFC] Non-wood fibres are expected to continue to play an important role in China’s future paper industry. [Worrell]

China intends to switch from a non-wood to a wood fibre base. The most likely reason is that there is insufficient delivery infrastructure to supply the large scale production facilities that are planned for China. China’s shift to a wood-based paper industry will affect global paper markets, particularly prices and availability of virgin and recovered fibre supplies. [Zakreski]

China has suddenly become the world’s second-largest paper consuming nation. Imports of both wood pulp and waste paper have shot up to feed China’s appetite for text books, newsprint and office paper. China does not have the forests to support such massive paper usage so it has become the world’s number one importer. [Godfrey]

The present structure and performance of the Chinese pulp and paper industry is unique in the world. This is to a large extent the result of the Chinese industrialisation policy adopted after the Communist Revolution. The policy favoured establishing small scale local and regional industries, based on non-wood fibre and domestic technology primarily due to the lack of domestic wood fibre and restricted foreign trade.

The key technological features of the Chinese non-wood pulp and paper sector are:
- Small scale and fragmented structure of the industry;
- Until recent policy changes environmental protection had only a low priority in the design and operation of the mills;
- Since the industry has been protected from the international and local competition, technical development has been slow and old manufacturing processes are still used resulting in wasteful use of raw materials and low product quality;
- Machine suppliers have also been domestic, and there has been practically no international or local competition. The research and development activities of machine suppliers have remained marginal with little driving force to develop more environmentally compatible equipment and process solutions. [Poyry, nr 7]

During the interviews in China we found out that China is still almost completely focussed on Chinese machine and process suppliers. They are simply not aware of foreign suppliers. When asking for companies, the answer was that there are hundreds of them, all small scaled. Asking for contact details resulted only in one (China BCEL International Engineering Co.Ltd.; www.bcel-cn.com) included with the warning that they don’t speak English and that it’s very hard doing business with them.

The general conclusion of the above is that the long term sustainability of the whole non-wood fibre based pulp and paper sector in China is questionable unless a new approach is taken to modernise the sector in such a way that both the effective environmental protection measures can be taken and the log-term cost and quality competitiveness is secured. Therefore, the new generation non-wood industry can survive only by building large scale integrated production units based on the best available, proven technology, which also can afford efficient environmental safeguards.

The total number of pulp and paper mills before shut-downs of the smallest mills in the 1990’s was about 10.000 and their production capacity around 24 million ton/y. Some decades ago it was even near 60.000. The average production of the mills was thus only about 2400 ton/y. The number of mills with a capacity of less than 5000 ton/y was about 9000. Some 4000 mills were closed down, representing about 2 million ton/y of production. At present the total non-wood pulp production is about 11-12 million ton/y and the total number of mills in operation is about 4000. [Poyry, nr 7]

The Chinese industry is characterized by thousands of small scale paper mills, most of which have no wastewater treatment facilities. Mills that rely on straw for papermaking use significant amounts of water and generate high levels of pollution, as the silica content in straw impedes the operational efficiency of certain components in the mills. Most mills lack water processing technology, which results in significant river pollution. Additionally, these smaller mills are powered largely by coal, contributing to a high level of greenhouse gas emissions, acid rain and mercury contamination in the region.

The share of non-wood fibre in papermaking furnish is likely to increase in the future only in tissue (from 15% tot 25%). In printing and writing papers, non-wood shares will come down due to runability challenges set by larger and faster paper machines, as well as stricter quality requirements of printers and publishers. For corrugating medium, the fall in non-wood use will be explained by rising need for high quality packaging in exports and in the domestic market. Also, non-wood fibre is
available mostly in inland and northern China, while the most of the board makers are in the south and east coast. [Poyry 2006 conclusion report]

Most of China’s paper and board production is concentrated in Shangdong, Zhejiang, Guangdong, Henan, Jiangsu, Hebei, Fujian, Hunan and Sichuan. These provinces produce about 83% of China’s total. The leading provinces for paper production out of non-wood fibres are Hunan, Anhui, Guangdong, Shaanxi, Shandong and Zhejiang. If further investigation is desired, concentrate on these regions, with the most emphasis on Shangdong.
3 Possible use of raw materials in The Netherlands

3.1 Introduction
During our desk research, a vast number of possible fiber material appeared for possible use for paper production. There are a lot of different options like straw, bagasse, esparto, bamboo, flax, hemp, jute, sisal, kenaf, cotton, linen, cereal, reed and beet pulp.

Unfortunately, not all grasses and crops are suitable to grow in a sea climate like in The Netherlands. Bagasse for example, a very promising source for paper manufacturing in China, is a residu of sugar cane. The climate in The Netherlands is not right to grow sugar cane, and importing it would be far too costly. Therefore, bagasse may be a promising alternative, but not in The Netherlands.

Assessment factors:
- Climate is a very relevant factor for determining whether a crop could be of value for the paper industry. However, other relevant factors should also be looked closely upon:
- When a crop can be grown in The Netherlands, we still have to find sufficient soil to grow it, and after harvesting, transport it to one or more production locations. We will deal with these subjects in this chapter. It is good to bear in mind that we did not research the possibility of competitiveness on the sourcing market.

3.2 Climate
The Dutch climate is typically temperate, with gentle winters, cool summers and rainfall throughout the year. So it is important to find crops that can be grown in this sea climate. Sugar cane for instance is not suitable as it is only found in subtropical and tropical areas, roughly from Spain to the Northern part of South Africa. In this section, we will discuss the suitability of crops in The Netherlands.

Straw and stalk fibers
Straw consists of the stalks of grasses, particularly of wheat, oats etcetera. Because of the appearance of wheat grasses all around the world, it also forms a possible source for paper and board production in The Netherlands. When looking further into that, it looks like a situation of history repeating itself. For many years, straw pulp was the major raw material for pulp, paper and paper board. In fact, 300 kt/yr of straw pulp was produced\(^1\). Production plants were closed mainly because of the environmental problems. Environmental issues are discussed in the next chapter. Straw seems to be a promising source.

\(^1\) Jong, S de; 'Non-wood fibre crops' Rural Industries Research and development corporation; November 1999; www.rirdc.gov.au
Bagasse

Bagasse is the remaining fiber after all sugar has been extracted from sugarcane. Sugarcane, as mentioned in the introduction of this chapter, grows roughly in regions between the Southern part of Spain and the Northern part of South Africa. Regions outside the (sub-)tropics, including The Netherlands, are not suitable for growing sugar cane. For countries within tropical regions, bagasse may be a feasible source, but probably there has to be competed on sourcing with the cane factories themselves, as bagasse is also used as a fuel.

Esparto

Esparto is used in paper manufacturing already. Its alternative name – Spanish grass – describes perfectly where to find the grass: in Spain and Northern Africa. There are two kinds of esparto: alfa and esparto, both becoming about 1.5 meters high. It was extensively used in Great Britain and Europe around 1850\(^4\). CEPI has studied the possibilities of esparto and encourages esparto grass usage in Tunisia\(^5\). However, it proves to be of little use for usage in The Netherlands: it needs dry sunny coasts to grow.

Bamboo

Bamboo is quite common in – for instance – China. Bamboo are giant fast-growing grasses that appear in tropical, but also more moderate climates. This means that there are sorts that are suitable for the Dutch climate!

Flax

Flax was used in The Netherlands and Belgium for producing linen. The plant can adapt itself to various sorts of soil and likes temperate climates. Nowadays, in the close region flax is grown in the southwestern part of The Netherlands, Belgium and the northern of France. Land used for flax has been tripled in the last 25 years to 100.000 hectares. However, almost all land increase took place in France.

Hemp

KCPK indicated that hemp as a possible resource is already investigated. However, we found that we should at least mention briefly the possibility of hemp as an alternative source for fibers. Needless to say that hemp is very suited to be grown in The Netherlands. Hemp – or better what can be produced from it – is one of the products The Netherlands are most notorious about. However, there are more ways to make use of hemp. One of those ways is to make paper. In old China, scripts of Confucius and Lao Tsu were published on hemp paper. To avoid complications: industrial hemp contains hardly any THC - the psychoallergeen in marihuana - and is


\(^5\) [http://www.tunisianindustry.net.to/guide_en/download/CEPI/id03.pdf](http://www.tunisianindustry.net.to/guide_en/download/CEPI/id03.pdf)
therefore harmless. Within Europe, industrial hemp is grown in France, the United Kingdom, Germany, Italy, Spain and The Netherlands.

**Jute and kenaf**

Jute grows in hot and humid climates, mostly in Bengal India, China and Brazil. It is unfitted to grow in The Netherlands, and therefore we did not investigate its possibilities further.

Kenaf is a fast growing plant and is often used as a substitute for jute. However, also kenaf requires a warm, moist (tropical or subtropical) climate, with plenty of water. Kenaf is seen as a promising substitute to virgin wood for paper production by the United States Department of Agriculture. For the record, kenaf grows mainly in Central Africa, USA and China.

**Cotton**

Cotton fiber is already used for making special grades of paper. For growing cotton, warm and humid climates with sandy soil is the most suitable. This means that Dutch climate and soil are not appropriate to cultivate cotton.

**Reeds**

Reeds form dense vegetations in delta areas of large rivers in Easter Europe, Africa and Asia. The usage of reed as a paper fiber source in The Netherlands has been investigated in the 1990’s. Unfortunately we did not recover the results of that investigation. Perhaps it is available in the KCPK’s archives.

**Reed canary grass**

Reed canary grass is a reed that is worth mentioning separately. Like “ordinary” reed, it is found in wet places, along the margins of rivers, lakes and pools. It is widely distributed across temperate regions of Europe, Asia and North America. Most important, in Sweden and Finland it is a suitable crop for short fiber pulp production. In The Netherlands, RCG is fairly common.

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6 [http://www.ecomall.com/greenshopping/kenafx.htm](http://www.ecomall.com/greenshopping/kenafx.htm)
7 [http://nl.wikibooks.org/wiki/Papier/Vezels_voor_papier](http://nl.wikibooks.org/wiki/Papier/Vezels_voor_papier)
8 Source: Michael Finell 'The use of reed canary-grass as a short fibre raw material for the pulp and paper industry; Doctoral Thesis Swedish university of Agricultural Sciences; Umea 2003
3.3 Logistics

Straw

Straw has a fiber yield of 4 tons per hectare per year. This results in 1.9 tons of pulp per hectare each year\(^9\). Unfortunately, there is a fierce competition with existing and emerging different applications, like feed for livestock, fuel for CO\(_2\)-neutral power generation and even construction works. Whether collection costs are high or low is unclear. Different sources contradict each other. De Jong stated in his article that Dutch production ceased because of the high collection costs\(^9\) while at least one other report states that fiber acquisition costs are comparable to those of wood pulp\(^11\).

Hemp

Hemp, if kept in stock, has to be conserved in 15% humidity at the most. In the United Kingdom, a company named Springdale has invented an on-farm processing unit for fiber hemp. It is not operational yet, but is expected to be finished in 2008\(^12\). Depending on the fertility of the soil, up to 15 tons of fibers per hectare can be harvested, resulting in 6.7 tons of pulp\(^7\). Other possible usage of hemp are seeds for nutrition (flour, oil) of cosmetics (oil). When it is possible to join up with a party that is interested in using the seeds, hemp may be available against low cost. However, until now it proves to be impossible to grow hemp that combines both oil and fiber. A Wageningen study (2002) showed a revenue of 8.000 kgs per hectare when using special purpose fiber hemp, while straw revenues drop to 1485 kgs per hectare when using double purpose hemp (Flanders, 2003).

Flax

When aiming for flax as a potential source, be aware of competition. Flax usually is known because of the production of linseed oil, a much more common application and important for the production of paints and linoleum. However, there is a special kind of flax: fiber flax. This one is specially grown because of its fiber.

Flax is sowed in the first half of April and harvested in the second half of July. Therefore, when flax would be used, large supplies should be built in order to be able to produce all year round.

Bamboo

Bamboo is common in almost every continent, except for Europe, where it did not survive the last ice age\(^13\). Bamboo sorts belong to the world’s fastest growing plants in the world, several tens of centimeters a day is not exceptional\(^13\). However, these are figures based on tropical conditions. Bamboo has a fiber yield of 4 tons/ha and a pulp yield of 1.6 tons/ha\(^14\).

Reeds

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\(^9\) Source: Non-wood fibre and global fibre supply; H. Pande; University of Toronto Faculty of Forestry, Toronto Ontario Canada

\(^10\) Jong, S de; ‘Non-wood fibre crops’ Rural industries Research and development corporation; November 1999; www.rrirdc.gov.au

\(^11\) Source: Susan Kinsella The environmental Paper Listening Study; Fiber Futures; sep 2004; www.paperlisteningstudy.org

\(^12\) Interprovinciaal Proefcentrum voor de Biologische Teelt (PCBT) vzw, Rumbleke, Belgium

\(^13\) From Innovation Focus, Innovation Support Organisation for Agriculture, Leuven, Belgium

\(^14\) Source: Non-wood fibre and global fibre supply; H. Pande; University of Toronto Faculty of Forestry, Toronto Ontario Canada
Similar to paper production plants, reeds can be found in the neighborhood of water. This creates a logistical advantage. Large scale harvesting may prove to be difficult as barges and amphibious boats may be needed\textsuperscript{15}. Annual dry mass production yields 5 – 10 tons/ha.

\textit{Reed canary grass}

As RCG is fairly common in The Netherlands, transport should not be the problem. It can be grown on most soil types, but grows best on light organic-rich soil types. Yields vary from 6-10 tons/ha dry matter depending on the harvesting period. Out of every 8 tons of fibers, 4 tons of pulp can be produced\textsuperscript{15}.

\subsection*{3.4 Remarks}

The one element that has not been taken into account yet is whether the crop is prepaid or not. Few crops may seem to be promising, but when we are refining our inventory to prepaid crops that can be used in The Netherlands, straw remains as the only suitable possibility.

There are developments which can be seen as a threat to the availability of non-wood fibers for the papermaking industry. Robert W. Hurter talks about a threat he calls bio-mania. Bio-mania he describes as the huge and growing interest in generating electricity and producing fuels from biomass, be it wood or non-wood. The US government has made a commitment to increase biofuel production to reduce dependence on imported oil. In Germany, incentives offered to biomass to biofuel converters and bio electricity producers are driving up wood costs, which has alarmed the pulp and paper industry. It is conceivable the same will happen to non-woods.

This could pose a significant threat to the use of nonwood fibre raw materials for pulp and papermaking as biorefineries could affect the availability and costs of the nonwoods for pulp and papermaking\textsuperscript{16}.

\begin{flushleft}
\textsuperscript{15} Source: PST
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\textsuperscript{16} Source: Robert W. Hurter; ‘Non-wood fiber – 2010 and beyond, prospects for non-wood paper production in asia pacific’; presented at APPITA 62\textsuperscript{nd} annual conference and exhibition; found on the internet; www.HurterConsult.com
\end{flushleft}
4 Possible future trends in non-wood fibre production and use in papermaking

There are a number of factors that may result in an increased use of currently available non-wood fibres in paper-making, and even an increase in production of non-wood fibres specifically for use in the papermaking industry.

From an environmental perspective, there is growing interest on the part of activist groups and individual consumers in “tree-free” papers that may help to drive an increase in paper production from non-wood fibres. Another contributing factor may be pending environmental legislation imposing new regulations on the disposal of agricultural waste fibres.

The regions that show the greatest change in the volume of non-woods used are North America and Europe, which traditionally have high levels of paper production combined with very low levels of non-wood usage, and Asia and the Pacific, which has always utilized a great deal of non-woods in the papermaking process. The Asia and the Pacific region will remain the largest user of non-wood fibre sources through the year 2010. India and China are likely to remain the two countries that rely most on non-woods. Non-woods also have the potential to increase in importance in Latin America and in Africa, where technology is being introduced and choices for capital investment are being made. These regions have the necessary climate and long growing seasons necessary to make non-woods an attractive alternative to pulpwood forest plantations. The worldwide consumption of non-woods increased by more than 50 percent between 1983 and 1994, and a further increase of more than 120 percent by the year 2010 is projected. Environmental problems related to the use of non-wood fibres coupled with storage problems and a limited growing season through much of the world, have combined to keep the fraction of non-woods being used in global pulp production at a fraction of the total capacity. [Pande]

For the Netherlands two other aspects are of importance:

- The decision by the authorities to produce green energy from burning (sorted) waste paper (burning of ‘unsorted’ waste paper already takes place as the household waste being burned consists for 25-30% of paper and board).
- Export of collected waste paper to the Far East.
5 INFORMATION FOR RESEARCH INTO STRAW

Looking at all the different non-wood fibres, only a very few will be attractive for the Netherlands after assessing all the factors mentioned in the introduction. Straw seems to be the first choice:

- It grows in our climate (in abundance);
- Is prepaid as a result of food production;
- Can be used in board production (with which we have experience).

The drawback is that there are competitive uses: animal fodder and bedding and in some cases for soil amendment. And possibly energy conversion. Straw is being chosen by a lot of countries and is researched often. Down here a selection of other straw related initiatives that can be helpful for further research.

- ARS (agricultural research) scientists in Albany, California, and their colleagues at Regale Corporation in Napa. http://www.nps.ars.usda.gov
- Chempolis; http://www.chempolis.com/
- Free Fiber (Metso); www.metso.com
- Centre for environmental strategy at the university of Surrey (Philip Sinclair)
- Natural Pulping AG / Natural Pulping GmbH
- Central Pulp and Research Institute (CPPRA)
- Second Harvest Paper Projects; Second Harvest Paper Project joins the skills and experience of three organizations, Markets Initiative, ForestEthics and Fiber Futures, to build mainstream market demand for paper made with agricultural fibres. Second Harvest Paper Project is organized to work with the pulp and paper industry to diversify their raw fibre base and to support the development of non-wood pulping technology that is more energy, water and chemical efficient. In the process farmers find new markets and mills pulp significantly fewer, ancient and endangered forests. http://www.marketsinitiative.org/resources/second-harvest-paper-project
- The NACO International system, devised in Foggia, Italy in 1982, claims that its recovery system can handle high levels of silica. The Ariga group in Australia intends to build a second NACO process for straw, but plans haven't materialized yet. It is not clear why other paper manufacturers don't seem interested in this process.
- Granit SA of Switzerland claims a new technology to solve the recovery problem. They're working on a pilot plant in Thonon, France, to prove the concept, which seems very promising. This technology is not mature either, and needs a couple of more years to develop.
- Weyerhauser spent a great deal of time and money in the 1990's figuring out a decent straw supply system, and figuring out the stakotech steam explosion system. Weyco built a complete pilot plant in Springfield, Oregon and made it work. Nevertheless Weyco decided not to pursue
straw pulping, and as of yet it is unclear what the exact reason for discontinuation was. The project reports are not public, but if you contact Bill Fuller at the Weyco research facility in Tacoma you may be able to find our more.

- A pulp and paper manufacturing group called ABC pulp and paper in India claims two patents and a pilot process proof of treating silica rich black liquor effluent from a straw pulping process. The process is defunct and has not been proved on industrial scale
- The Finnish company Conox claims similar results. Conox Limited, a Finland based company dedicated to developing cleaner technologies for use in the paper and pulp industry in developing countries.
- Universal Pulping of Eugene, Oregon claims a low-temperature, low pressure, low emission process particularly suitable for non-wood pulping. The process, patented by Eric Prior, was evaluated by the pulping labs at NCSU, WSU and the University of Washington with very promising results. Although promising, the technology is not "off-the-shelf" yet, it has to be scaled up and debugged first. UP is working on a pilot project to establish the technology.
- In Canada a lot of research is done in using straw as a recourse for paper production. See: [Stern]
- A research study done for applying non-wood fibres in Australia in Paper and panel industry is written by Jong, S de [Jong]; www.rirdc.gov.au. The research includes financial assessments.
- Research Labs: A large body of knowledge on straw pulping and papermaking has been built up at the University of Washington in Seattle: Prof. Bill McKean and Mike Lewis are experts in the field. Other Universities in the region (WSU and OSU) have also contributed to the field, Bill Pan at WSU in Pullman, WA is a renowned expert on using pulping effluents as fertilizer.
- The Canadian Pulp and Paper Research Institute PAPRICAN in Vancouver BC has recently carried out a number of excellent studies on straw pulping for the Canadian pulp and paper industry, contact Paul Watson or Andy Garner for more info there.
- Med Byrd runs an excellent non-wood pulp and paper lab at NCSU in North Carolina.
- Adolph Koppensteiner, formerly working for Kvearner (Austria), is an expert on non-woods. adolf.koppensteiner@akerkvaerner.com
- HurterConsult is one of the experts in the field of NWF usage. See for initiatives: www.hurterconsult.com.
- Finland, Canada, USA, UK, Australia are all researching the topic.
  a. Finland
  - Finland has a shortage of hardwoods and is intensively looking at non-wood alternative sources of short fibre. Of particular importance is the use of hemp that produces a substantial crop over the three or four months of warm summer weather.
  b. Canada
  - The Alberta Research Council is actively working on non-wood pulping technology using agricultural residues such as oilseed flax.
  c. United Kingdom
    - BioRegional is developing the MiniMill; The Wolfson Centre at Brunel University in London
    - Biocomposites Centre is working on Flax and hemp pulping technology
    - Hemcor is working on and advocating technology for the use of hemp for paper manufacture
    - Apsley Paper Trail initiative is using the Frogmoor mill in cooperation with Cross and Bevan to run trials on various non wood pulp supplements to recycled fibre
  d. Australia
    - Arisa Ltd. are in the process of establishing a wheat straw mill in Victoria that will use the NACO process.
  e. USA
    - A number of initiatives are gaining momentum in the USA.
  f. Netherlands
Research into non-wood fibre pulping technologies, and the application of non-wood fibre to enhance wood and recycled paper qualities, is being done through the Agro Technological Research Institute. [Hunt]; http://www.marketsinitiative.org/resources/second-harvest-paper-project
Extracts of the interviews

Hereafter, you will find the extracts of the interviews we had with the different parties.
The Chinese industry uses a lot of non wood fibre:

- Straw (22% of paper produced in China). Not much increase to expect.
- Reed
- Bagasse
- Bamboo (more and more)
- Wood (22% of paper produced in China)
- Recycled fibre (56% of paper produced in China)

To produce high grade paper, additional wood pulp should be used.

Smaller pulp mills will close down because of

- to high energy consumption (coal fired)
- water pollution (rivers)

Government initiated projects to reduce pollution and so small mills will be forced to close.

In future no small mills will be built. Scale is important even for non wood fibre mills. Governments encourages to make use of straw, reed, bagasse and bamboo. 45% of the raw materials used is recycled fibre. In future 10.000.000 ton pulp will be imported.

Most paper produced from recycled fibre is exported, because a lot of goods produced in China is exported. The recovery rate in China is low. Recycled fibre is coming from Hong Kong, Europe and USA.

Processes using Reed and Bagasse are mature. Straw converting processes are technologies in progress. Straw is the most used non-wood fibre in China (20.000.000 tons/y). But there are some problems:

- straw pulp is difficult to dewater on the paper machine
- the high silica content gives recycle problems with cooking chemicals
- burning of black liquor gives problems because of silica deposits in the burners.

Some research is done on this subject: in Shandong paper mills have co-operated with CTTI. Especially in the area of cooking and washing.

- Straw pulp contains very small amounts of lignin.

Low grade tissue can be produced of 100% straw pulp

Cartonboard can be produced of 100% straw pulp
Higher grades must be produced from wood pulp.

Chinese company that engineers and builds non-wood pulp processes:
China BCEL International Engineering Co.Ltd.
www.bcel-cn.com
Contact: Liyao; Huang Zuren; Huang Yunji.

Minimum production size for straw pulp mill >50,000 ton/y because of the high costs of the water treatment.

In the future the production % of straw will go down although the total usage will go up.

High grade tissue will increase but is expected to stay below 30%.

Every 4 years there is an international non wood fibre research meeting (Named: International Nonwood Fiber Pulping and Papermaking Conference) held in China. Last was in 2006 (Huanan Industry; Guangzhou).

China does the most research on nonwood fibres followed by USA and Canada.

Tissue samples:
- yellow roll: straw pulp
- roll 2: 50% recycled fibre & 30% virgin & 20% other
- roll 3: 80% bagasse (middle grade)
- roll 4: 100% wood
Visit to: China Technical Association of the Paper Industry (CTAPI)

Date: 13-07-2007

Present: Yang Maoxian (Senior engineer); Liyuhua (vice secretary-general, senior engineer); interpreter; M. Adriaanse (report); A. Bolk

In China 6.5000 million tonnes of paper is produced in 2006. The raw material used is:

- Wood 22%
- recycled paper 56%
- straw 22%; later we were told 110 million ton of straw based paper was produced

Small mills producing less than:

- 1000 ton of straw based paper and
- 1700 ton of wood based paper

have to close down because of too much water pollution.

They amount of mills for straw pulp don’t increase.

Machines used in these mills coming from China; having hundreds of machine suppliers.

High grade paper is produced from wood; middle grades from straw and low grades from recycled fibre. More and more tissue is produced from wood pulp as it was recycled fibre and straw in former years. Production of straw based paper is centred in Central China.

In China not much research is being done in straw pulping as the process is mature. The research that is being carried out by CTAPI and China University of technology (SCUT; contact person will be sent). There is also research being done by foreign countries (Canada; Finland (University Helsinki)) of which sometimes student come over to China.

CTAPI asked whether we have experience in water cleaning technology. They heard that Saica mill in Spain had water cleaning technology installed. (Paques?)

They are interested in working together with the Dutch Paper industry. Stay in contact with ms Liyuhua

**General impression:**

- meeting through an interpreter (which is non familiar with the business and is not very fluent in English) is a big disability and hurdle in a good and smooth conversation.
- In the beginning the impression was that CTAPI was surprised we didn’t knew the numbers and details of the Chinese as well as of the Dutch paper industry. Through body language it became clear that they didn’t want the interpreter to tell all things that CTAPI was discussing with her. Or that they didn’t believe the numbers given.
CTAPI did start the meeting by asking directly what the purpose of the meeting was and what all our questions were. As soon as we asked already known facts and some more into technical details, they answered that that wasn't the aim of the meeting.

Although they seem to have a lot of experience in this field they weren't able to solve the water polluting problem of the straw mills.

Later on when we asked what we, based on our competencies, could offer to them changed the conversation. Suddenly without asking for it she answered my earlier question about machine supplier and was helpful in thinking with us. She also offered to find out contact persons for us at universities.
Kadant only supply parts for the non-wood fibre production lines. The chemical pulp preparation is sold by Andritz and Metso.

Silica is causing the problem of environmental pollution. This is the reason that no new production lines are being built.

There is no new research being carried out in Non wood fibre (not by universities or research institutes). In contrast with research into quick growing wood species!

A lot of recycled fibre mills are being built for Liner; corrugated medium; corrugated white board and newsprint.

Tissue is being produced from virgin fibre which will be replaced more and more by Mixed office waste.

In China are 3000 paper mills in total. 15 mills produce over 1.000 kton/a; 50 mills over 500 kton/y. Local companies supply fibre lines because the grow rate is to big and the big suppliers are to expensive.

China Paper Association organises every other year the China Paper Exhibition in Beijing or Shanghai (this year 18-20 September 2007).