GLOBAL FIBRE SUPPLY STUDY
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Recovered and Non-wood Fibre: Effects of Alternative Fibres on Global Fibre Supply

Warren E. Mabee and Harshad Pande

Working Paper GFSS/WP/04

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Peter N. Duinker
Faculty of Forestry, Lakehead University, Thunder Bay, Canada

Gary Bull
Forest Products Division, Forestry Department, FAO, Rome

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Recovered and Non-wood Fibre: Effects of Alternative Fibres on Global Fibre Supply

by

Warren E. Mabee
(Faculty of Forestry, University of Toronto, Toronto, Canada)

Harshad Pande
(Faculty of Forestry, University of Toronto, Toronto, Canada)

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FOREWORD

In late 1995, the FAO Forestry Department initiated the Global Fibre Supply Study (GFSS) with an outlook to the year 2050. The study was recommended by the FAO Advisory Committee on Pulp and Paper (now the Advisory Committee on Paper and Wood Products). The general objective of the study is to contribute reliable data, information, forecasts and analysis of industrial fibre sources in order to promote sustainable forest management.

The GFSS will include a compilation of the latest available inventory data, including recovered and non-wood fibre, focusing primarily on the sources of industrial fibre as raw material for the sawmilling, wood-based panels, and pulp and paper industries. It will also include a projection and analysis of future developments in fibre supply, based on explicit consideration of the major factors affecting supply.

The GFSS is unique among FAO studies in that special emphasis is placed on collection and compilation of fibre volume inventory and growth data for the developing regions - Africa, Asia-Pacific, and Latin America and the Caribbean. The study complements other FAO work, such as the Asia-Pacific Forestry Sector Outlook Study and the upcoming Forest Resources Assessment 2000. FAO is also updating its statistics on forest plantations and developing a method for estimating fibre volumes from non-forest areas in the tropical regions. Available data from these studies will be included in the GFSS.

The major products of the GFSS will include:

- A database accessible on-line through the Internet providing estimates of commercial wood volumes from natural, semi-natural and plantation forests;
- An on-line interactive fibre-supply model incorporating key determinants of supply;
- A statistical and descriptive report on the data and three fibre-supply scenarios which are based on factors deemed to be the most critical;
- A working paper describing in detail the methods for data compilation, gap filling, data validation, forecasting and definitions, survey forms and country list;
- A series of additional working papers on sustainable forest management, improved forest productivity from industrial forest plantations, fibre-supply modelling, recovered and non-wood fibre, and other topics; and
- An issue of *Unasylva*, FAO's quarterly journal on forestry and the forest industry, dedicated to the theme of global fibre supply.

This paper, solicited by the GFSS and co-authored by Warren Mabee and Harshad Pande, shows the potential significance of recovered and non-wood fibre in the global fibre-supply picture. We sincerely hope that it contributes productively to the world-wide dialogue on sustainable forest management for fibre and other values.

Olman Serrano
Chief
Wood and Non-wood Products Utilization Branch
Forest Products Division

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This series of working papers have seen the contribution of many silent partners. Our colleagues in the Forestry Department provided much needed advice on several issues. In addition, there have been many outside reviewers from different research institutions and technical cooperation agencies who have provided valuable information. We also want to thank our special assistant Ms Elisa Rubini who guided each report through the many technical hurdles in document preparation.

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SUMMARY

This study has investigated the possible effects of alternative fibre availability on global fibre supply until the year 2010. By examining each of the three scenarios, it is possible to view a range of availability for recovered and non-wood fibres which represents a set of possible outcomes. The scenarios have been designed to provide a high and low estimate of alternative fibre availability that define the limit of these possibilities, as well as describing a general trend into the future.

Overall results indicate that alternative fibre supply can range from approximately one-half the projected paper production levels to 95 percent of this level (Figure 1). The projected trend in alternative fibre supply indicates that alternative fibres can account for 52 percent of the total paper production level. Thus, in theory, over half of the world's supply of paper can be made from alternative fibre sources by the year 2010.

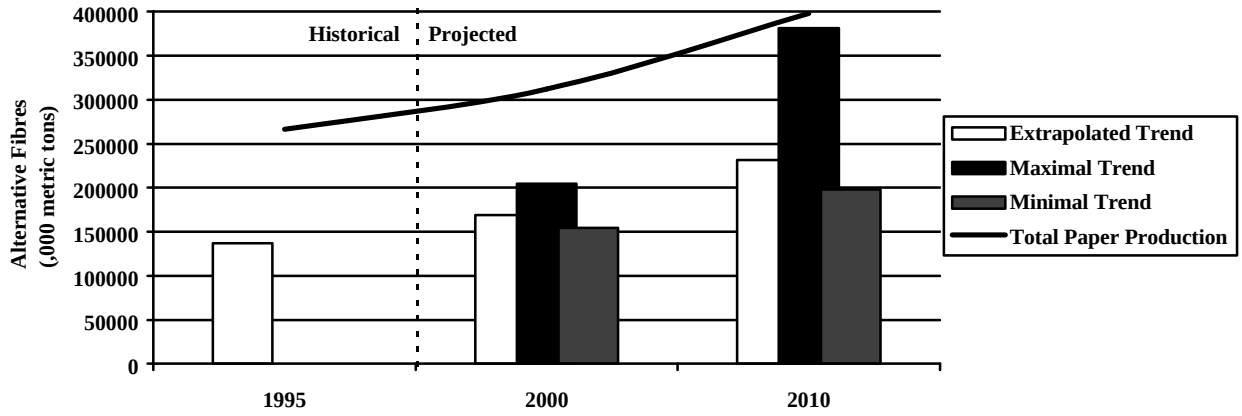


Figure 1: Total alternative fibre supply (3 scenarios)

As part of the FAO Global Fibre Supply Study (GFSS), this report will contribute a body of historical data on wastepaper recovery and non-wood fibre use. These data will be used in GFSS modelling efforts that will provide a comprehensive picture of global fibre availability. The projected future levels of alternative fibre use, as reported in this paper, will not be used *per se* in the final GFSS report, but instead will provide a reasonable range of alternative fibre use, at the national level, which can be applied in GFSS modelling efforts.

1. INTRODUCTION

As we move into the twenty-first century, the global fibre supply will change extensively. The intense competition for resources between corporations and countries around the world means that alternative fibre sources, such as recovered and non-wood fibres, will become more prevalent and desirable. At the same time, most industrialized countries are becoming increasingly concerned about deforestation and the impact of fibre extraction on the environment. This has resulted in widespread support for the practice of more sustainable forms of forestry, and has provided impetus towards the development of alternative fibre sources.

A recovered-fibre product may refer to any paper or wood product that uses some post-consumer fibre waste. This waste could come from any virgin-fibre product that the consumer has used, from paper to lumber. The largest source of recovered fibre today is wastepaper collected through recycling programmes, and the largest use for these recovered fibres is in papermaking.

Non-wood fibres are non-woody cellulosic plant materials from which papermaking fibres can be extracted. The most widely used non-woods for papermaking are straws, bagasse, bamboo, hemp, kenaf, jute, sisal, abaca, cotton linters, and reeds. Most non-woods are annual plants that develop full fibre potential in one growing season.

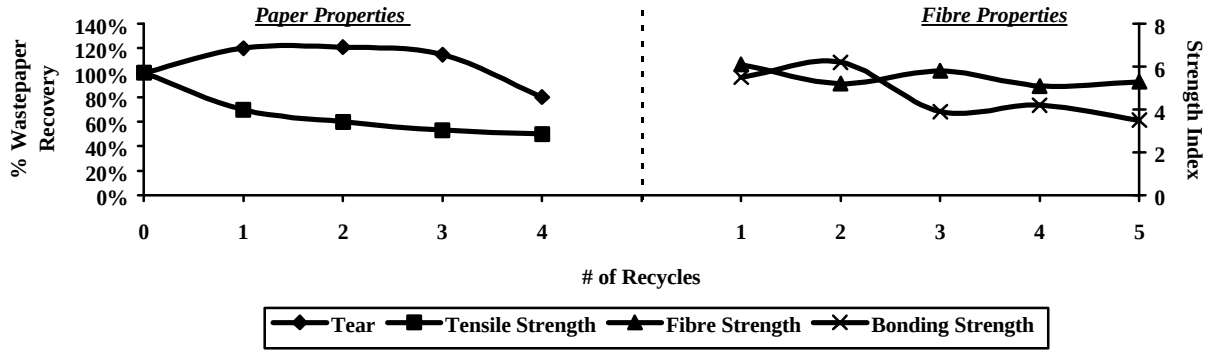
This paper has been prepared as part of the Global Fibre Supply Study, a project of the Forestry Department of the Food and Agriculture Organization of the United Nations. As such, the report endeavours to ascertain possible impacts of recovered fibres and non-wood fibres on the total global fibre supply until the year 2010. The emphasis of the report is on establishing and analysing baseline data and preparing outlook scenarios for supply and utilization of recovered wood and virgin/recovered non-wood fibre.

1.1 RECOVERED FIBRES

1.1.1 Paper and fibre properties

Recovered fibre refers to any fibre that is recycled, that is to say, used more than once in the manufacture of a paper or board product. Recycling has become a high-profile issue in most industrialized countries over the past ten to twenty years, and this is reflected in the high levels of wastepaper recovery that these countries report. In countries less industrialized, paper use is much lower and wastepaper recovery less of a concern. Those regions of the world currently experiencing economic transition or social unrest, such as the Former USSR and certain parts of Eastern Europe and the Middle East, also show erratic or no wastepaper recovery.

In the recycling process, there are usually many unknowns, including the fibre species, the number of times that the fibre has been recycled, and the pulping method used in fibre production. Traditionally, the impact of recycling has been examined through measuring the quality of the paper produced after a controlled series of pulping, digesting, and recovery. The fibre quality, in terms of strength, flexibility, and bondability, can also be measured. While the individual results of such testing vary greatly, the overall trends are fairly consistent (Figure 2).



(Sources: Mackee 1971; Howard and Bichard 1992; Smook 1992)

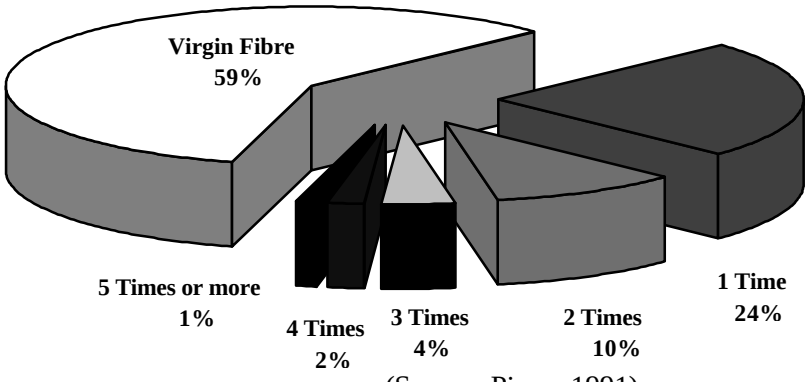
Figure 2: Effect of recycling on fibre and paper properties

The main factor affecting the recyclability of paper is the pulping method used. It has been shown that high-yield pulps, such as chemi-thermomechanical pulp (CTMP) and thermomechanical pulp (TMP), respond better to recycling due to their ability to reabsorb water after being dried in paper [Scallan and Tigerström 1991]. Lower-yield chemical pulps, such as soda or kraft, tend to become more brittle and therefore less flexible as the number of recycles increase. This greatly reduces the recyclability of some of these pulps.

For all pulps, the first recycle causes the greatest change in any paper or fibre property. Most paper properties tend to decline, although some measurements, such as tear, may show temporary increases [Horn 1975; Van and Gerischer, 1982]. Declines in paper properties seem to arise from the reduction of fibre bonding ability [Oye *et al.* 1991; Scallan and Tigerström 1991]. This reduction may be due to hornification, a stiffening and/or hardening of the fibre, which in turn causes a drop in the number and strength of interfibre bonds [Pierce 1991]. The intrinsic strength of the fibre may also decrease, although some researchers have reported no change [Van and Gerischer 1982] or even increases [Bobalek and Chaturvedi 1989] in individual fibre strength properties. In most cases, however, changes in paper and fibre properties tended to level out after four or five recycles, implying that the most degradation takes place in the first few cycles.

1.1.2 Fractions in recycled paper

Given the information in Figure 2 and above, it may be inferred that four or five recycles is the uppermost limit that can be achieved in fibre recycling. This view has been supported by Pierce [1991], who calculated that in repetitive recycling with a blend of 60 percent virgin fibre and 40 percent recycled fibre, only 1 percent of the fibres are used five or more times (Figure 3). At least one research team, however, disputes this figure. Nguyen *et al.* [1991] stated that with continued increases in waste paper recovery and advances in recycling technology, the average life expectancy of recycled fibres in paper will increase.



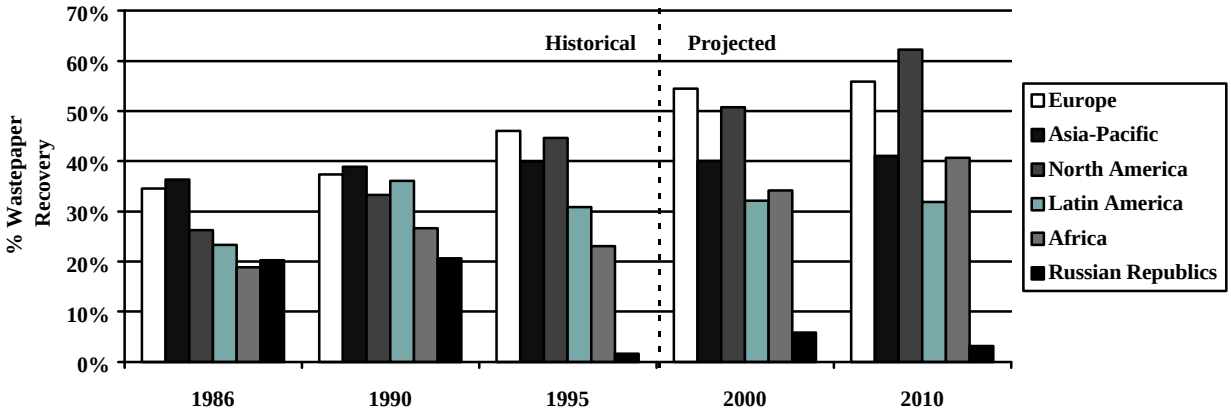
(Source: Pierce 1991)

Figure 3: Percent of recycled fibre after continual recycles.

It may be inferred from Figure 3 that recovered fibres do not last forever. It is also important to note that wastepaper, like any other fibre source, does not provide a 100 percent yield in the papermaking process. In fact, the yield on recovered fibres is about 80 percent [Smook 1992]. However, with improvements in technology, recovered fibre yield will almost certainly increase [Nguyen *et al.* 1991]. Therefore, the amounts of recovered fibre reported in this paper refer to gross quantities, rather than the theoretical net yield.

1.1.3 Trends in wastepaper recovery

For the past decade, there have been great increases in the amounts of paper recycled. There have also been tremendous fluctuations due to regional disturbances such as war or natural disasters. The trends in wastepaper recovery have been tabulated for six world regions: North America, Latin America, Asia-Pacific (including Australia), Africa, Europe, and the Former USSR. Using published figures from around the world [Pulp and Paper International 1988; 1990; 1992; 1994; 1996], a comprehensive picture of historical trends in wastepaper recovery can be assembled (Figure 4). By projecting these data forward to the year 2010, possible future levels of wastepaper recovery are shown (Figure 4).



(Source of historical data: Pulp and Paper International 1988; 1990; 1992; 1994; 1996) (Projected data by the authors)

Figure 4: Percent waste paper recovery by region, historical and projected

From the historical data (1986-1995), it can be seen that distinct trends emerge for each of the six regions. Four showed great improvement, with overall wastepaper recovery rates increasing in each by almost 10 percent; these four are the North and Latin American, European, and Asia-Pacific regions. The two exceptions are Africa and the Former USSR. Both these regions have suffered from major political turmoil or have endured major natural disasters; this has made wastepaper collection and accurate reporting difficult. However, the total production levels in each of these regions is low enough that they have little impact on the cumulative global trend towards increased wastepaper recovery.

When historical trends are projected into the future, four of the six world regions experience increases in wastepaper recovery. North America, Europe, Africa, and the Asia-Pacific regions should each experience increased recovery if current trends prevail. Latin America will maintain its current level of recovery, but little or no gain is forecast for this region. Finally, the Former USSR will continue to experience decreases in recovery rates that reflect the current negative trends in this area.

1.2 NON-WOOD FIBRES

1.2.1 Fibre dimensions

Data on average dimensions of various non-wood plant pulp fibres as compared to dimensions of wood pulp fibres (Table 1) show 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 fibres is small, resulting in lower coarseness from these pulps. Such fibre dimensions provide an idea of the potential usefulness of these pulps in papermaking. In fact, from technical and quality viewpoints, any grade of paper can be produced by using the appropriate combination of non-woody plant fibres.

1.2.2 Rationale for use

Increasing demand for a wide range of pulp-derived products and concerns over future wood fibre supply, coupled with a recent interest in “tree-free” papers, have caused a renewed interest in non-woods as a fibre source for the global pulp and paper industry. The advancement of agricultural practices and pending environmental restrictions on the disposal of agricultural waste fibres have also paved the way for the use of non-wood fibres.

Forest preservation by many national governments, and increasing environmental awareness on the part of large sectors of the public, have led to a focus on developing new, renewable fibre sources. There will be an increased use of unconventional raw materials, such as grass and agricultural residues, for papermaking to supplement wood [Mall and Upadhyay 1989]. While the current global total forest area is approximately 3.8 billion ha, estimates of the forest area presently available to meet world fuel and/or fibre requirements are closer to 2.1 billion ha, or 55 percent of the total [Hagler 1995]. Two nations in particular are important to the global outlook. Russia holds over 90 percent of the conifer forests that extend from Eastern Europe into the Former USSR region, while Brazil controls nearly 70 percent of the Latin American

region's hardwood production forests [Hagler 1995] (Table 2). These forest areas are key elements in balancing the global fibre supply equation.

Table 1: Fibre dimensions of non-wood plant fibres

Non-wood fibre (by species)	Average length (mm)	Average diameter (Tm)
Abaca (Manila hemp)	6.0	24
Bagasse (depithed)	1.0 - 1.5	20
Bamboo	2.7 - 4.0	15
Corn stalk and Sorghum (depithed)	1.0 - 1.5	20
Cotton fibre	25.0	20
Cotton stalks	0.6 - 0.8	20 - 30
Crotalaria (sun hemp)	3.7	25
Esparto	1.5	12
Flax straw	30.0	20
Hemp	20.0	22
Jute	2.5	20
Kenaf bast fibre	2.6	20
Kenaf core fibre	0.6	30
Rags	25.0	20
Reeds	1.0 - 1.8	10 - 20
Rice straw	0.5 - 1.0	8 - 10
Sisal	3.0	20
Wheat straw	1.5	15
Wood fibre (by species group)	Average length (mm)	Average diameter (Tm)
Temperate zone coniferous woods	2.7 - 4.6	32 - 43
Temperate zone hardwoods	0.7 - 1.6	20 - 40
Mixed tropical hardwoods	0.7 - 3.0	20 - 40
Eucalyptus	0.7 - 1.3	20 - 30

(Source: Atchison and McGovern 1993)

Table 2: Estimated production forests

Region	Conifers (million ha)	Hardwoods (million ha)	Total (million ha)	Percentage (%)
Europe	98.3	45.5	143.8	7.0
Asia-Pacific and Africa	101.1	301.8	402.9	19.5
North America	286.6	170.2	438.8	21.3
Latin America	9.0	660.5	669.5	32.4
Former USSR	291.8	118.6	410.4	19.9

(Source: Hagler 1995)

As the global demand for paper and paper products rises, it becomes increasingly evident that the forests of the northern hemisphere, which now supply the bulk of the world's fibre requirements, will be called upon to produce even more fibre for global consumption. Paper production consumes a substantial portion of the national wood harvest in the developed countries of the north. In 1983, it was estimated that the production of paper products required about 35 percent of the commercial wood harvest world-wide, and this figure is projected to grow to 50 percent by the year 2000 [Chandler 1993]. In the United States, 27 percent of the 1996 timber harvest was destined for domestic pulpwood production [Anonymous 1990]. These trends indicate a need to explore the use of non-wood fibres for papermaking.

1.2.3 Trends in use

Wood is a relatively new raw material in papermaking. Historically, paper was made exclusively from non-wood plant fibres. The first true production of paper is credited to T. S'ai Lun in the year 5 AD in China. This first paper was apparently made from textile wastes, old rags, and used fish nets, which consisted of the fibres of true hemp and China grass (ramie) [Atchison and McGovern 1993].

Currently, wood is the major raw material for the global pulp and paper industry. Some non-woods are still used, however, especially in China and other Asian countries. At the present time, the most common non-wood fibre is straw (Table 3). This material accounts for 46 percent of total production, followed by bagasse (14 percent) and bamboo (6 percent) [Atchison 1995]. Other non-wood fibres, such as cotton, hemp, sisal, and kenaf, are also becoming more important in the manufacture of pulp and paper. Projected values for 2000 and 2010 continue this trend. Non-wood species currently used only sporadically in the pulp and paper industry will become more important, as production of non-woods expands beyond the present focus in East Asia to a more global scale.

Table 3: Leading non-wood fibres

	Total papermaking pulp capacities (thousand metric tons)					
Raw materials	1985	1988	1990	1993	2000	2010
Straw	6 166	5 260	7 623	9 566	12 318	17 014
Bagasse	2 339	2 267	2 646	2 984	3 516	4 387
Bamboo	1 545	1 674	1 468	1 316	1 137	807
Miscellaneous *(cotton, reeds, sisal, jute, hemp, abaca, kenaf, flax)*	3 302	6 366	6 870	6 870	10 168	14 276
Total papermaking non-wood capacity	13 352	15 567	18 607	20 736	25 832	35 624
Total paper and paperboard production	178 558	225 887	238 939	250 359	312 056	397 780
Percentage non-wood	7.4%	6.9%	7.8%	8.3%	8.3%	9.0%

(Sources: Atchison 1995; FAO 1997)

2. CURRENT LEVELS OF PRODUCTION AND CONSUMPTION BY REGION

Recovered fibres and non-wood fibres are considered alternatives to wood as raw materials in today's pulp and paper industry. As a result, standardized reports on production, consumption, imports and exports of these materials are not always available. Therefore, an examination of these fibre sources requires certain assumptions to be made. When dealing with recovered fibres, an assumption was made early on that all fibres used in paper could be recovered. This is not true in practice, as there are grades and types of papers which are rarely recovered due to their use. Common examples might be waxed paper used in fast-food wrappings, and of course sanitary papers.

Wastepaper recovery is not the same as wastepaper use. Use of wastepaper requires large capital investments for mills and machinery, while wastepaper recovery can be achieved at a much lower cost. Moreover, as people in developed countries become more environmentally aware, there is a tendency to establish recycling programmes before the capacity to use the wastepaper stream is established. Therefore, not all wastepaper being recovered is necessarily consumed. The literature on this subject often takes great pains to establish levels of recovery and consumption [FAO 1992; FAO 1994]. In this study, the emphasis is on recovery and the theoretical amounts of paper available from the recovered material.

In the treatment of non-wood fibres, this paper merely considers the availability of the material and its suitability for pulping. However, many non-woods are too valuable in other industries to be economically used in papermaking today. Cotton, for instance, is much more widely used for textiles than for paper, because the value of the final product is so much higher.

2.1 CURRENT USE OF RECOVERED FIBRES

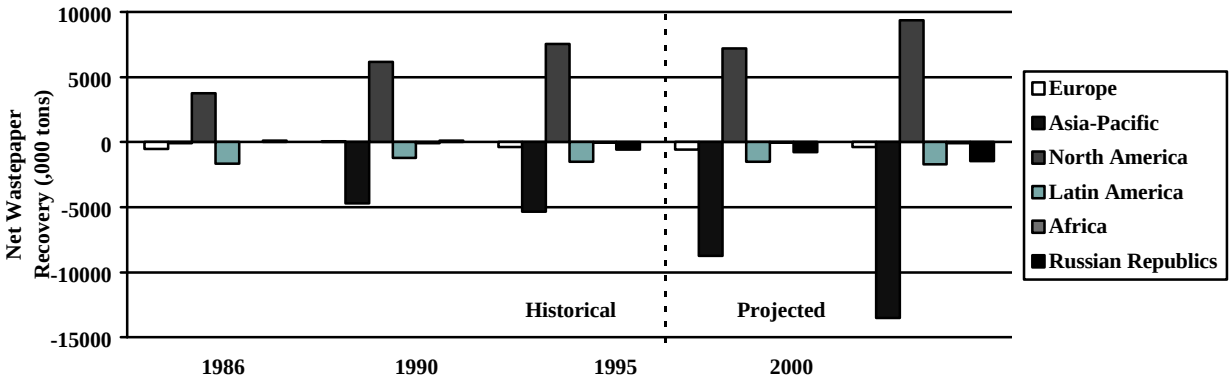
At the current time, most world regions are consuming slightly more wastepaper than they are recovering (Table 4). There is indeed a thriving world market for wastepaper. The North American region has consistently been the largest supplier of this material, and has in fact maintained an almost virtual monopoly on wastepaper exports. Of the other five global regions, the Asia-Pacific region has the largest demand for wastepaper goods. Europe, Africa, Latin America and the Former USSR each have a low level of demand that probably could be served through reserves of wastepaper from more prosperous years, or from slight increases in national recovery levels in the member countries of these regions.

The reliance of the Asia-Pacific region on North American wastepaper could prove to be a problem in future years. It can be assumed that with extensive growth in this region, the demand for wastepaper will continue to rise (see Figure 5), possibly outstripping the supply that North America can offer [Guest 1996; Kenny 1996]. Should this happen, wastepaper recovery will have to rise greatly in the Asia-Pacific region to meet demand.

Table 4: Wastepaper recovery to consumption ratios, 1995

Region	Wastepaper recovery (thousand tons)	Recovery of total production (%)	Wastepaper consumption (thousand tons)	Ratio of recovery:consumption (x:1)
Europe	31923	46	32297	0.99
Asia-Pacific	35603	40	40946	0.87
North America	41999	45	34427	1.22
Latin America	4354	31	5853	0.74
Africa	901	23	924	0.98
Former USSR	40	2	629	0.06

(Sources: Pulp and Paper International 1988; 1990; 1992; 1994; 1996)



(Sources of historical data: Pulp and Paper International 1988; 1990; 1992; 1994; 1996)
(Projected data by the authors)

Figure 5: Net waste paper recovery by region, historical and projected

2.2 CURRENT AVAILABILITY OF NON-WOOD FIBRES

It has been estimated that the total availability of non-wood fibres world-wide is approximately 2.5 billion metric tons per year (Table 5) [Atchison 1995; McCloskey 1995]. This number, however, refers to all non-wood fibre sources, including those used in the textiles and agriculture industries. It is difficult to ascertain the exact amount of fibres that are available for the pulp and paper industry, as market factors and the conditions experienced during the growing season will have a large impact on fibre supply. Recent estimates are that the current papermaking capacity for non-wood fibres is approximately 20 736 000 metric tons, which is less than 1 percent of the total supply [Atchison 1995; McCloskey 1995; FAO 1997].

Table 5: Estimated global availability of non-wood fibres

Raw material	Estimate 1: (thousand metric tons)	Estimate 2: (thousand metric tons)
Wheat straw	600 000	739 700
Rice straw	360 000	465 200
Barley straw	195 000	218 500
Oat straw	55 000	50 800
Rye straw	40 000	41 900
Grass seed straw	3 000	-
Flax (oilseed)	2 000	-
Corn stalks	750 000	727 300
Sorghum stalks	252 000	104 700
Sugarcane bagasse	102 200	100 200
Cotton stalks	68 000	35 900
Leaf fibres (Sisal, Hennequen, Maguay)	500	-
Reeds	30 000	-
Bamboo	30 000	-
Cotton staple	18 300	18 000
Stem fibres (Kenaf, Jute, etc.)	13 700	-
Papyrus	5 000	-
Cotton linters	2 700	2 300
Esparto grass	500	-
Sabai grass	200	-
Hemp fibres	200	-
Abaca	80	-
Cotton mote	-	900
Total	2 528 380	2 505 400

(Sources: Atchison 1995; McCloskey 1995)

2.3 WORLD-WIDE PULPING CAPACITIES FOR NON-WOOD FIBRES

The Asia-Pacific region has clearly invested the most time and resources into the pulping of non-woods (Table 6). In particular, China and India are leaders in the use of non-woods for papermaking. In North America, Latin America, Europe, the Former USSR, and even Africa, the abundance of forest resources has limited the need for non-wood fibre sources, and these regions lag far behind the Asian example of large-scale non-wood pulping. Few changes are expected between the historical values for 1993 and the projected values for 1998 (Table 6). The Asia-Pacific region is expected to maintain its current position, producing almost 90 percent of the world's non-wood pulps. Each of the other regions is currently using non-woods in relatively small amounts. However, it is evident from the individual data that certain countries, like Egypt and Greece, are almost exclusively using non-woods as their fibre supply. Changes in any of these countries could have a great impact upon world-wide non-wood use.

Table 6: Non-wood pulping capacities of the world's 21 top producers, 1993 and 1998

Country	1993		1998 *(Estimated)*		% of world pulping capacity	
	Non-wood pulping capacity (thousand metric tons)	% National pulping capacity	Non-wood pulping capacity (thousand metric tons)	% National pulping capacity	(1993)	(1998)
Asia-Pacific Region						
China	15 246	86.9	16 830	84.3	73.5	71.7
India	1 307	55.5	2 001	61.3	6.3	8.5
Pakistan	415	100	415	100	2.0	1.8
Indonesia	267	22.1	267	10.1	1.3	1.1
Thailand	209	100	509	100	1.0	2.2
Turkey	103	16.5	103	16.5	0.5	0.4
Iraq	101	100	101	100	0.5	0.4
Taiwan	100	20.0	100	20.0	0.5	0.4
Iran	90	25.0	90	25.0	0.4	0.4
Viet Nam	86	60.1	100	40.0	0.4	0.4
Regional sub-total	**17 924**	**--**	**20 516**	**--**	**86.4**	**87.4**
Latin American Region						
Mexico	321	29.2	324	29.3	1.6	1.4
Peru	298	95.2	296	95.2	1.4	1.3
Colombia	218	45.1	218	37.2	1.1	0.9
Brazil	196	3.1	238	3.3	1.0	1.0
Venezuela	185	75.2	187	75.4	0.9	0.8
Argentina	140	14.6	140	12.8	0.7	0.6
Cuba	108	100	108	100	0.5	0.5
Regional sub-total	**1 466**	**--**	**1 511**	**--**	**7.1**	**6.4**
North American Region						
USA	179	0.3	204	0.3	0.9	0.9
Regional sub-total	**179**	**--**	**204**	**--**	**0.9**	**0.9**
European Region						
Greece	150	85.7	160	84.2	0.7	0.7
Spain	140	7.9	141	7.7	0.7	0.6
Italy	120	13.3	120	13.3	0.6	0.5
Romania	102	10.9	102	10.9	0.5	0.4
Regional sub-total	**512**	**--**	**523**	**--**	**2.5**	**2.2**
African Region						
Egypt	127	100	127	100	0.6	0.5
South Africa	99	6.4	99	6.4	0.5	0.4
Regional sub-total	**226**	**--**	**226**	**--**	**1.1**	**1.0**
Total top 21 countries	**20 305**	**--**	**22 980**	**--**	**97.9**	**97.9**
World total	**20 736**	**--**	**23 471**	**--**	**100**	**100**

(Source: McCloskey 1995)

3. FUTURE TRENDS IN ALTERNATIVE FIBRE PRODUCTION

Predicting wastepaper recovery rates or the use of non-woods in the future is difficult. In the case of wastepaper recovery, the number of variables involved is great. For every country, the variables include population, the level of development, the industrial capacity for wastepaper, the presence and condition of necessary infrastructure such as roads, and the political and public opinions toward recycling paper. A country that currently produces and imports small amounts of paper and paperboard, such as Angola in the African region, could theoretically begin importing paper and recycling at an exponential rate. It is also possible that the next 15 years will see little or no development in certain countries around the globe. In comparison, many highly developed countries of Western Europe and North America have implemented paper recycling to a level where further increases in wastepaper recovery are likely to be linear reflections of the overall growth of the pulp and paper industry.

Non-wood fibre use should demonstrate different trends than recovered fibre use, as the variables involved are different. A country's climatic and soils conditions will have a great influence on its ability to cultivate non-wood species. Historical practices in cultivation will also affect the country's ability to produce non-woods, as the farms necessary to grow the various species of plants must be available and suitable for the task. The presence or absence of available forests within the country will have a large effect on the decision of governments or private individuals to cultivate non-woods. This last factor is especially true in desert or barren countries, where non-wood crop species may be the only renewable fibre source available.

In this paper, we have examined the historical production of paper and paperboard products, and projected trends to the year 2010. This was carried out for every paper-producing nation in the world. To predict future trends in paper and paperboard production, historical data were regressed linearly and the resultant trends were then extended to 2010. The projections rest on the following assumptions:

1. In the case of a declining trend in paper and paperboard production, it is assumed that the country's output will not fall beneath 10 percent of the highest reported national production level. This precludes predicting levels of zero production, and reflects the fact that established mills in these countries would likely be used if they are present.
2. Paper and board exports may not go above 90 percent of the overall paper and board production. This limit is designed to restrict export levels to a realistic fraction of the total production.

The resulting trends of paper and paperboard production were used as a baseline for three scenarios each of wastepaper recovery and non-wood production. While these trends were not made using FAO estimates, they tended to fall in line with the 1997 Provisional Outlook Report [FAO 1997]. They are also fairly consistent with values provided by Jaakko Pöyry Consulting, Inc. [Cesar 1995].

3.1 WASTEPAPER RECOVERY

3.1.1 Three scenarios defined

Scenario 1: Extrapolated Wastepaper Recovery

The first scenario for wastepaper recovery is based on a simple projection of historical data to the year 2010. This was done by conducting linear regressions on published production data, and then projecting the resulting trends forward. The following assumptions were made to prevent the trends from becoming clearly unrealistic.

1. Wastepaper recovery cannot fall beneath 10 percent of the highest reported recovery level, or above 100 percent of [P&B Production + Imports - Exports], whichever is lower.
2. If there are no reported values for paper and board production or wastepaper recovery after 1990, then production and recovery are assumed to have stopped and zero is used.

Trend extrapolation has some limitations. The method does not differentiate between highly developed and undeveloped countries, which may experience radically different changes in wastepaper recovery over the next few decades. It also does not make any allowances for natural disasters or political upheavals, both of which could drastically affect the industrial output of individual nations.

Scenario 2: Optimal Wastepaper Recovery

The second scenario is that of an ideal world, in which goals and targets for wastepaper recovery would be met by every country and high levels of recycling would be possible. In determining a wastepaper recovery target level for each region, figures were chosen based on current recycling levels in each of the six global regions and on previous predictions of growth. For instance, Europe, being a compact, highly developed area with traditionally high levels of recycling, was given a target of 90 percent wastepaper recovery. This figure reflects that given by FAO in previous market reviews [FAO 1992; FAO 1994]. This figure is also indicative of a theoretical maximum for recycling, as it is unlikely that levels of much greater than 90 percent wastepaper recovery will be reached in a realistic world. Ideal levels for the other regions were based on our estimates of the potential best recovery that each region could expect in the time period allotted. They were set as follows: Asia-Pacific, 75 percent; North America, 75 percent; Latin America, 50 percent; Africa, 50 percent; and the Former USSR, 40 percent. Each regional goal was compared with independently projected pulp and paper production levels for that region, to confirm that the target was realistic [Bayard Palmer and Haid 1995; Nilsson 1995; Reed 1995]. Some of these figures, including the European value, approximate published goals [FAO 1994]. Others were chosen on the basis of our professional judgement. This scenario should be treated as an analysis of theoretical maximums.

Scenario 3: Minimal Wastepaper Recovery

The third scenario makes an initial assumption that no further advances will be made in wastepaper recovery, and that recovery levels will therefore stagnate around the world. An analysis of the historical data shows that this has happened in some countries. This scenario

takes the worst-case approach, and shows the minimal levels that wastepaper recovery could attain should certain environmental initiatives fail.

3.1.2 Results and discussion

Scenario 1: Extrapolated Wastepaper Recovery

In Scenario 1, North America's projected 68 percent recovery rate is higher than any of the other six regions (Table 7). The European recovery rate will be approximately 56 percent, which is far below the region's stated and assumed goal of 90 percent recovery [FAO 1994]. Recovery rates experienced by other regions range from low gains in Africa and Asia-Pacific, to no gains in the case of Latin America, to negative trends as shown for the Former USSR.

Table 7: Wastepaper recovery levels by region, 1986-2010 - Scenario 1

Region		1986	1995	2000	2010
Europe	(%)	34.6	46.0	54.5	55.9
	(thousand metric tons)	19 011	31 923	40 916	49 907
Asia-Pacific	(%)	36.3	39.9	39.9	41.1
	(thousand metric tons)	17 252	35 603	43 487	62 670
North America	(%)	26.2	44.6	44.6	62.3
	(thousand metric tons)	20 029	41 999	51 190	73 588
Latin America	(%)	23.3	30.8	30.6	31.9
	(thousand metric tons)	2 431	4 345	5 220	6 788
Africa	(%)	34.6	23.1	23.1	40.7
	(thousand metric tons)	561	901	1 296	1 814
Former USSR	(%)	20.3	1.6	5.9	3.2
	(thousand metric tons)	2 000	40	15	10

If each region continues to follow present-day trends, the only regions that show significant gains in recovery rates are North America (45-67 percent recovery) and Africa (31-44 percent recovery), while Europe may experience a moderate increase (47-56 percent recovery) (Table 7). The Asia-Pacific and Latin American regions are projected to be stagnant, gaining little or nothing in terms of increased recovery rates. The Former USSR will experience a significant decline in wastepaper recovery if current trends continue. However, should the countries comprising this region enter a period of relative political peace, it can be expected that great increases would be forthcoming in both paper production and paper recycling, especially in Russia itself [Nilsson 1995].

Scenario 2: Optimal Wastepaper Recovery

Under Scenario 2, almost 300 000 000 tons/yr of wastepaper (total) will be recovered in 2010 (Table 8). This is almost five times the amount of wastepaper available as of 1986. Of all the regions, the greatest increase in recovery levels and rates take place in the Asia-Pacific region. This would be reflected by a decrease in reliance upon imports of North American recovered paper to meet recycling quotas. North America, Europe, and Latin America must also improve recovery rates significantly to meet the targeted goals, but to a lesser degree than Asia-Pacific.

Africa and the Former USSR would require relatively insignificant gains in total wastepaper recovery, as paper consumption is projected to be rather low in each of these regions.

Table 8: Wastepaper recovery levels by region, 1986-2010 - Scenario 2

Region		1986	1995	2000	2010
Europe	(%)	34.6	46.0	60.7	90.0
	(thousand metric tons)	19 011	31 923	45 573	80 418
Asia-Pacific	(%)	36.3	39.9	51.6	75.0
	(thousand metric tons)	17 252	35 603	55 695	114 373
North America	(%)	26.2	44.6	54.7	75.0
	(thousand metric tons)	20 029	41 999	55 257	88 646
Latin America	(%)	23.3	30.8	37.2	50.0
	(thousand metric tons)	2 431	4 345	6 053	10 647
Africa	(%)	34.6	23.1	32.1	50.0
	(thousand metric tons)	561	901	1 216	2 227
Former USSR	(%)	20.3	1.6	14.4	40.0
	(thousand metric tons)	2 000	40	35	119

Scenario 3: Minimal Wastepaper Recovery

Under the third scenario, recovery rates are held stagnant at their 1995 levels. However, because more and more paper and paperboard products are being produced, the amount of wastepaper being recovered is constantly increasing. Thus, the Asia-Pacific region, while recovering wastepaper at a lower rate than either Europe or North America, actually would recover the most wastepaper under this scenario due to the high levels of paper manufacture expected in this region (Table 9). However, the North American and European regions could show significant gains in recovery levels as well, due to the continual growth that the pulp and paper sectors in these regions may experience.

Table 9: Wastepaper recovery levels by region, 1986-2010 - Scenario 3

Region		1986	1995	2000	2010
Europe	(%)	34.6	46.0	46.0	46.0
	(thousand metric tons)	19 011	31 923	34 369	41 227
Asia-Pacific	(%)	36.3	39.9	39.9	39.9
	(thousand metric tons)	17 252	35 603	43 299	60 882
North America	(%)	26.2	44.6	44.6	44.6
	(thousand metric tons)	20 029	41 999	45 041	52 731
Latin America	(%)	23.3	30.8	30.8	30.8
	(thousand metric tons)	2 431	4 345	4 976	6 576
Africa	(%)	34.6	23.1	23.1	23.1
	(thousand metric tons)	561	901	875	1 029
Former USSR	(%)	20.3	1.6	1.6	1.6
	(thousand metric tons)	2 000	40	4	5

3.2 NON-WOOD FIBRES

3.2.1 Three scenarios defined

Scenario 1: Extrapolated Non-wood Fibre Use

The first scenario for non-wood fibre use is based on a simple projection of historical data to the year 2010. This was done by conducting linear regressions on published production data, and then projecting the resulting trends forward. The method does not make allowances for radical shifts in the use of non-woods as the new millennium approaches. If the USA, for instance, decided to implement a non-wood-fibre cultivation programme, the actual production of non-woods would shift radically.

Scenario 2: Optimal Non-wood Fibre Use

The second scenario is that of an ideal world, in which a set goal for non-wood use would be met by every country. To build this scenario, figures were chosen based on current non-wood fibre use for each of the six global regions. For instance, the Asia-Pacific region was given a target of 50 percent non-wood fibre content for all paper and paperboard products by the year 2010, as the use of non-woods is already high in this region. Ideal levels for the other regions were based on estimates of the potential best use that a region could expect in the time period allotted. They are: Europe, 5 percent; North America, 5 percent; Latin America, 5 percent; and Africa, 5 percent. The Former USSR was not included in these calculations due to a lack of data.

Scenario 3: Minimal Non-wood Fibre Use

The third scenario makes an initial assumption that no further advances will be made in non-wood fibre use, and that use will therefore stagnate in every nation around the world. An analysis of the historical data shows that this has happened in the past in some countries. This scenario takes the worst-case approach, and shows the minimal levels that non-wood fibre use could attain.

3.2.2 Results and discussion

Scenario 1: Extrapolated Non-wood Fibre Use

The Asia-Pacific region will almost double its current consumption of non-wood fibres, as the amount of paper and paperboard products being manufactured with non-wood fibre increases (Table 10). China and India, the two main producers of non-wood pulps, are the nations that are driving this trend. This increase translates into an incredible rise in demand for non-wood fibre supply, which may or may not be present in the area. In the other regions of the world, the historical trends in non-wood fibre use are generally unchanging. Thus, consumption of non-wood fibres is predicted to remain a constant percentage of total paper and paperboard consumption in each of these regions [McCloskey 1995].

Table 10: Non-wood fibre use by region, 1993-2010 - Scenario 1

Region		1993	2000	2010
Europe	(% Regional paper production)	0.8	0.6	0.5
	(thousand metric tons)	512	580	558
Asia-Pacific	(% Regional paper production)	23.4	23.7	24.1
	(thousand metric tons)	17 924	24 236	33 396
North America	(% Regional paper production)	0.2	0.2	0.3
	(thousand metric tons)	179	248	335
Latin America	(% Regional paper production)	11.7	11.3	10.8
	(thousand metric tons)	1 466	1 684	1 711
Africa	(% Regional paper production)	7.5	8.1	9.1
	(thousand metric tons)	226	276	298
Former USSR	(% Regional paper production)	--	--	--
	(thousand metric tons)	--	--	--

Scenario 2: Optimal Non-wood Fibre Use

The regions showing the greatest change in the volume of non-woods used are North America and Europe, which have traditionally high levels of paper production combined with low levels of non-wood use, and the Asia-Pacific region, which has always used a great deal of non-woods in the papermaking process (Table 11). Other regions show large percentage increases in non-wood use under this scenario, but low paper-production levels mean that this does not affect overall production greatly. While this demand represents a massive increase in the amount of non-wood fibres needed, the present-day supply is more than adequate to meet it [McCloskey 1995].

Table 11: Non-wood fibre use by region, 1993-2010 - Scenario 2

Region		1993	2000	2010
Europe	(% Regional paper production)	0.8	2.5	5.0
	(thousand metric tons)	512	2 196	5 446
Asia-Pacific	(% Regional paper production)	23.4	34.4	50.0
	(thousand metric tons)	17 924	33 967	69 165
North America	(% Regional paper production)	2.0	2.2	5.0
	(thousand metric tons)	179	2 319	6 545
Latin America	(% Regional paper production)	11.7	15.1	20.0
	(thousand metric tons)	1 466	1 998	3 157
Africa	(% Regional paper production)	7.5	10.6	15.0
	(thousand metric tons)	226	309	492
Former USSR	(% Regional paper production)	--	--	--
	(thousand metric tons)	--	--	--

Scenario 3: Minimal Non-wood Fibre Use

Results of Scenario 3 approximate those of Scenario 1 in many ways (Table 12). Historically, levels of non-wood use have remained fairly constant. In this scenario, however, even the small increases shown in Scenario 1 are omitted. Under Scenario 3, the only part of the world that

will be seriously using non-woods is the Asia-Pacific region. Non-wood use in every other region will remain an insignificant fraction of overall pulp and paper production.

Table 12: Non-wood fibre use by region, 1993-2010 - Scenario 3

Region		1993	2000	2010
Europe	(% Regional paper production)	0.8	0.8	0.8
	(thousand metric tons)	512	699	878
Asia-Pacific	(% Regional paper production)	23.4	23.4	23.4
	(thousand metric tons)	17 924	23 146	32 391
North America	(% Regional paper production)	0.2	0.2	0.2
	(thousand metric tons)	179	224	267
Latin America	(% Regional paper production)	11.7	11.7	11.7
	(thousand metric tons)	1 466	1 546	1 844
Africa	(% Regional paper production)	7.5	7.5	7.5
	(thousand metric tons)	226	218	244
Former USSR	(% Regional paper production)	--	--	--
	(thousand metric tons)	--	--	--

4. OVERALL PRODUCTION AND ALTERNATIVE FIBRE USE

There is a difference between the paper production levels used for recovered fibres and those used for non-wood fibres. The production levels of non-wood fibre use are compared against the total production values, both historic and projected, on a regional and global basis. These values do not take into account imports or exports of pulp and/or paper, but are rather the gross values of total production. However, when one compares recovered fibres to total production, a modified figure for paper production must be used. Therefore, the *modified total production* value referred to below is total paper production plus paper imports, less paper exports.

The rationale behind this system is simple. Non-wood pulps represent a virgin or primary source of fibrous material available for paper production. Whether or not the paper produced from non-woods is exported or used internally is irrelevant. Recovered fibres, on the other hand, become available from the total fibre present in the country or region. Thus, it is important to take into consideration the imports and exports of paper that becomes the source of recovered fibres.

4.1 SUMMARY FOR RECOVERED FIBRES

Of all the regions, the Asia-Pacific region will become the largest producer of paper and paperboard products by the year 2010, eclipsing the North American and European regions (Table 13). This could have several effects on global supply and demand of recovered fibres. Should the recovery of wastepaper in all regions continue along current trends, the users of wastepaper in the Asia-Pacific region will be driven to import more and more wastepaper from other parts of the world, primarily North America. If the excess supply in North America does not match the demand in the Asia-Pacific region, the most likely result would be higher costs for wastepaper as a commodity world-wide.

Table 13: Three scenarios of wastepaper recovery vs. total modified paper production, 1986-2010

Region	(thousand metric tons)	1986	1995	2000	2010
Europe	Modified paper production	54 879	69 442	75 121	89 353
	WP recovery *(Scenario 1)*	19 011	31 923	40 916	49 907
	WP recovery *(Scenario 2)*	19 011	31 923	45 573	80 418
	WP recovery *(Scenario 3)*	19 011	31 923	34 369	41 227
Asia-Pacific	Modified paper production	47 488	89 179	108 459	152 497
	WP recovery *(Scenario 1)*	17 252	35 603	43 487	62 670
	WP recovery *(Scenario 2)*	17 252	35 603	55 965	114 373
	WP recovery *(Scenario 3)*	17 252	35 603	43 299	60 882
North America	Modified paper production	76 430	94 139	100 957	118 195
	WP recovery *(Scenario 1)*	20 029	41 999	51 190	73 588
	WP recovery *(Scenario 2)*	20 029	41 999	55 257	88 646
	WP recovery *(Scenario 3)*	20 029	41 999	45 041	52 731
Latin America	Modified paper production	10 413	14 145	16 271	21 294
	WP recovery *(Scenario 1)*	2 431	4 345	5 220	6 788
	WP recovery *(Scenario 2)*	2 431	4 345	6 053	10 647
	WP recovery *(Scenario 3)*	2 431	4 345	4 976	6 576
Africa	Modified paper production	2 985	3 902	3 793	4 453
	WP recovery *(Scenario 1)*	561	901	1 296	1 814
	WP recovery *(Scenario 2)*	561	901	1 216	2 227
	WP recovery *(Scenario 3)*	561	901	875	1 029
Former USSR	Modified paper production	9 850	2 512	246	298
	WP recovery *(Scenario 1)*	2 000	40	15	10
	WP recovery *(Scenario 2)*	2 000	40	35	119
	WP recovery *(Scenario 3)*	2 000	40	4	5
Total modified paper and board production		202 045	273 319	304 847	386 090
Total wastepaper recovery *(Scenario 1)*		61 284	114 820	142 124	194 777
% Recovery		30.3%	42.0%	46.6%	50.5%
Total wastepaper recovery *(Scenario 2)*		61 284	114 820	164 100	296 429
% Recovery		30.3%	42.0%	53.8%	76.8%
Total wastepaper recovery *(Scenario 3)*		61 284	114 820	128 564	162 450
% Recovery		30.3%	42.0%	42.2%	42.1%

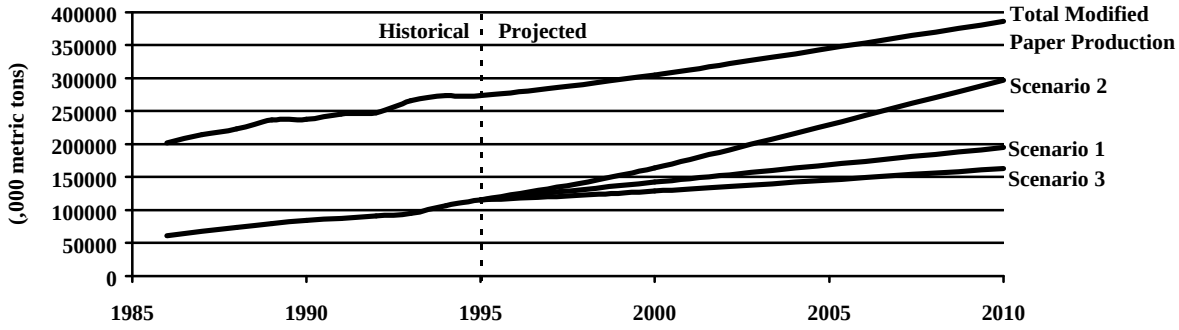


Figure 6: Three scenarios of wastepaper recovery vs. total modified paper production

As paper consumption continues to increase within the Asia-Pacific region, the availability of wastepaper in this region should become a key concern for the pulp and paper industry as well as the panelboard industry. Scenario 2 indicates just how large a wastepaper resource is available, should the infrastructure needed to recover the material be created.

Of all the regions, only two do not show trends toward relatively high levels of wastepaper recovery. Africa and the Former USSR are regions with great potential for growth, and projections for these regions should be treated carefully. Great changes should be expected in these regions over the next half-century, if not over the next decade.

4.2 SUMMARY FOR NON-WOOD FIBRES

Of all the regions and under each scenario, the Asia-Pacific region will remain the largest user of non-wood fibre sources through the year 2010 (Table 14). Native non-wood species suitable for fibre production exist in these regions, and the technology to utilize them for fibre is already in place in many countries in this region. India and China will likely remain the two countries which rely the most upon non-woods.

Non-woods have the potential to become important in Latin America and Africa, where technology is being introduced and choices for capital investment being made. These regions have the necessary climate and long growing seasons necessary to make non-woods an attractive alternative.

The North American and European regions are unlikely to use non-woods extensively, due to the climate in these regions and the presence of existing, highly-developed wood processing technologies. While no data is available, non-woods are also unlikely to become a major source of fibre in the Former USSR, due to adverse climatic conditions and short growing seasons.

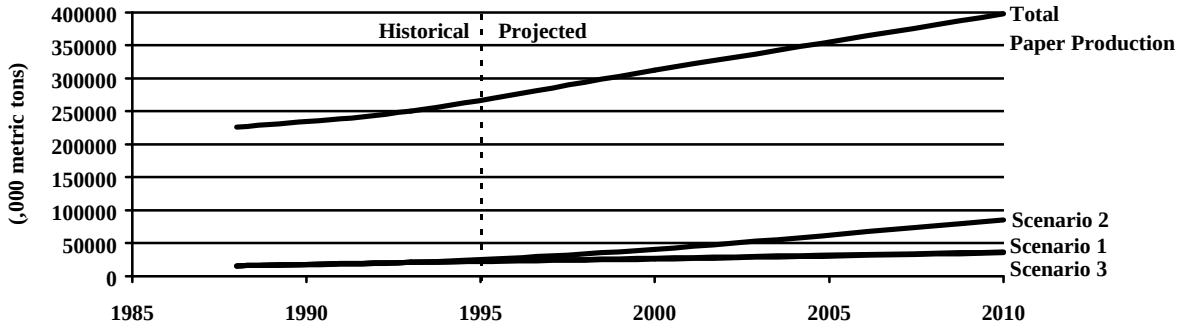


Figure 7: Three scenarios of non-wood fibre use vs. total paper production

Table 14: Three scenarios of non-wood fibre use vs. total paper production, 1988-2010

Region	(thousand metric tons)	1988	1993	2000	2010
Europe	Total paper production	64 805	69 304	86 707	108 914
	Non-wood pulp capacity *(Scenario 1)*	--	512	580	558
	Non-wood pulp capacity *(Scenario 2)*	--	512	2 196	5 446
	Non-wood pulp capacity *(Scenario 3)*	--	512	697	878
Asia-Pacific	Total paper production	52 169	68 769	98 850	138 331
	Non-wood pulp capacity *(Scenario 1)*	--	17 924	24 236	33 396
	Non-wood pulp capacity *(Scenario 2)*	--	17 924	33 967	69 165
	Non-wood pulp capacity *(Scenario 3)*	--	17 924	23 146	32 391
North America	Total paper production	95 988	94 091	109 758	130 899
	Non-wood pulp capacity *(Scenario 1)*	--	179	248	335
	Non-wood pulp capacity *(Scenario 2)*	--	179	2 319	6 545
	Non-wood pulp capacity *(Scenario 3)*	--	179	224	267
Latin America	Total paper production	9 560	11 306	13 226	15 783
	Non-wood pulp capacity *(Scenario 1)*	--	1 466	1 684	1 711
	Non-wood pulp capacity *(Scenario 2)*	--	1 466	1 998	3 157
	Non-wood pulp capacity *(Scenario 3)*	--	1 466	1 546	1 845
Africa	Total paper production	2 588	2 353	2 922	3 280
	Non-wood pulp capacity *(Scenario 1)*	--	266	276	298
	Non-wood pulp capacity *(Scenario 2)*	--	266	309	492
	Non-wood pulp capacity *(Scenario 3)*	--	266	218	244
Russia	Total paper production	10 750	4 536	593	593
	Non-wood pulp capacity *(Scenario 1)*	--	--	--	--
	Non-wood pulp capacity *(Scenario 2)*	--	--	--	--
	Non-wood pulp capacity *(Scenario 3)*	--	--	--	--
	Total paper and paperboard production	225 887	250 359	312 056	397 780
	Total non-wood capacity *(Scenario 1)*	15 567*	20 736	27 140*	36 484*
	% Non-wood pulp of total paper	6.9%	8.3%	8.7%	9.2%
	Total non-wood capacity *(Scenario 2)*	15 567*	20 736*	40 789	84 805
	% Non-wood pulp of total paper	6.9%	8.3%	13.1%	21.3%
	Total non-wood capacity *(Scenario 3)*	15 567*	20 736*	25 832	35 624
	% Non-wood pulp of total paper	6.9%	8.3%	8.3%	8.3%

* Note: A miscellaneous amount of non-woods is included in some totals, due to the nature of the historical data [Atchison 1995].

5. RECYCLING OF NON-WOOD FIBRES

In considering the impact of recovered and alternative fibres on the global fibre supply, at some point the recyclability of non-wood fibres must be established. There is little information on the recycling potential of non-wood fibres. Preliminary studies have examined the effects of pulping and recycling on kenaf. It has been shown that most non-woods have a lower lignin content than wood, and that it is easier to delignify non-woods as they have a lower activation energy [Cesar 1995]. There have also been investigations into the changes suffered by fibres during the recycling of wheat-straw pulps showing that wheat-straw pulp did not behave differently than wood pulp during recycling. While non-woods generally have lower strength, crystallinity, and fibre length than do wood fibres, the trends that can be observed from recycle to recycle are approximately equivalent. This means that recycling fibres from either source would result in approximately the same degree of change.

For this investigation, it has been assumed that recovered non-wood fibres behave exactly as recovered wood fibres in the recycling process. This assumption, while borne out by preliminary assessments, may in fact be wrong. It may be necessary to institute a correction factor for the non-wood fibre fraction in determining the overall amount of fibre that could be recovered from non-wood paper sources.

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GLOBAL FIBRE SUPPLY STUDY
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The Global Fibre Supply Study (GFSS) of the FAO Forestry Department operates under the guidance of an Advisory Committee on Paper and Wood Products. The GFSS has produced a number of publications. To obtain a list, or to order a single copy of this publication free of charge, please contact:

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The paper examines the impact that alternative fibres, specifically recovered (recycled) and non-wood fibres, have had and may have on the global fibre supply. The properties and availability of each type of fibre are discussed. Based on historical data, three scenarios of future fibre supply were created: a projection of historical trends, an optimal model of high use of both types of fibre, and a minimal model of conservative use. A range of future availability of non-wood and recovered fibre could then be constructed. It was found that, in total, non-wood and recovered fibres currently comprise approximately 51 percent of the current levels of paper and paperboard production. The three scenarios predicted that this fraction would range from 50 to 90 percent of the world's paper production level by 2010. The projection of historical trends shows a slow increase in alternative fibre content, culminating in a level of about 55 percent of total global paper production by 2010.