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Long-Term Changes in the Location and Structure of Forest Industries

1.0 INTRODUCTION

The World Bank/WWF Alliance, in concert with the Council on Foreign Relations is exploring the hypothesis that more efficient use and increased productivity of forest resources could, by 2050, ensure that most of the world's needs for industrial forests products could be derived from a comparatively small proportion of intensively managed global forests.

This background paper examines the structural evolution of the global forest industry, with particular reference to the key factors likely to affect the long-term spatial distribution. The paper is based on an initial search of relevant literature. The scope is necessarily broad, and in the interest of brevity, the material presented is very much of an overview nature. Virtually all of the topics covered merit in-depth analysis.

2.0 HISTORIC OVERVIEW

2.1 Introduction

The utilization of forest resources has a very long history, and as Mather (1990) has noted, most of the problems faced in the 20th century are not new. The management, use and control of forests; the shrinkage of forest resources; scarcity (real or perceived) of wood supply; and ecological damage such as floods and soil erosion have all been subjects of debate and concern for centuries. Indeed, Britain experienced timber shortages in the 17th century; nearly every European country has learned that complete denudation of forest cover without reforestation has profoundly negative social and economic consequences; and as recently as 1920 the United States was consuming almost five times the annual growth of its forests (Cox et al 1985). In Mather's words, "we can in fact learn from the past".

2.2 Evolutionary phases and transitions

The utilization of wood and the exploitation of the world's forest resources can be broadly characterized by three sequential phases that flow from the basic evolution of man from "hunter-gatherer" to farmer. The shift from one phase to the next is accompanied by a transitional period. The importance of these transitions is highlighted by Mather who suggests that the major problems of forest resource use occur at times of transition. The phases are differentiated by the nature and diversity of goods and services sought from the forest, the importance given to wood production as a management goal and the legitimacy given by the public to differing approaches to forest management.

In the initial or pre-industrial phase, forests are perceived to be an unlimited resource, both for the wood itself and for the land, which can be converted to farming. There is no obvious need for conservation or management, and in consequence, the resource-base declines. The industrialization phase typically begins with an unexploited old-growth forest. Wood is "mined" and as forest regions are depleted, the exploitation moves further afield, resulting in spatial shifts of the industry. Harvest levels exceed growth, and timber inventories decline. However, harvests that exceed growth, declining inventories and deforestation do not *necessarily* lead to unsustainability (Vincent and Binkley 1990). Where an effective stumpage market operates, rising prices provide an incentive for increased timber growth and more efficient processing, which together tend to be self-correcting, at least in terms of market values.

Rising prices indicate scarcity, and can in turn trigger moves to resource conservation as the nature of wood harvesting shifts from extensive exploitation to varying degrees of intensive forest management. Sedjo (1993) noted that the world is still largely dependent on natural, old-growth forests rather than "farmed" or

managed forests. While this is less true in parts of Europe where managed and planted forests have long been the norm, it is, in Sedjo's view, only a matter of time before the transitional stage is reached globally. That said, it should also be noted that there is alack of uniformity globally, most particularly between developed and developing regions and even within countries.

Mather (1993) suggests that the transition from a reliance on old-growth forests to more intensively managed forest or plantations is "one clear feature of the present century". This transition has been driven in Europe by a slowing down of population growth and increasing food crop yields (hence less need for agricultural land) and the substitution of wood as a fuel source by electricity and petroleum products. These factors, coupled with changing values and perceptions of the forest lead to what Mather (1993) describes as the "post-industrial forest." He points out that this term is not synonymous with "multiple use" but rather it relates to popular perceptions and expectations of planted forests in both private and public ownership.

Mather contends that the shift to the post-industrial forest will be reflected in differential growth patterns and a "southward adjustment" in wood production and processing.

2.3 Two basic models

The history of Forest resource exploitation and development in the Mediterranean Basin and in North America provides two basic models which can be applied at least in general terms to most regions of the world. Mather (1990) outlines these histories in some detail and they are summarized in the paragraphs following.

2.3.1 The Mediterranean Basin

The Mediterranean experience, beginning with classical Rome and Greece, is largely negative. Forest utilization featured destructive exploitation on a massive scale, driven by the fuelwood and grazing/farmland requirements of an increasing population. Despite such pressures, some of the forest remained, due mainly to a combination of technical (coppicing, sewing, planting and thinning techniques were applied centuries ago) and organizational ability. In the 19th century, the introduction of the railway provided access to previously unexploited forests. Further deforestation occurred, facilitated by weak institutions and a lack of control. Although there has been a partial transition to conservation and improved utilization efficiency, Mather notes that the Mediterranean forest resource model "does not bode well for the future of the forest world". He notes that it also provides a model that has been followed by much of the developing world in the second half of the 20th century.

2.3.2 The United States

Following the pre-industrial period, the period from the 17th to the 19th century was marked by a rapid depletion of the original forest cover, with fuelwood harvesting and then clearing for agriculture being the primary causes. The forests seemed vast and inexhaustible. As one area was exhausted, timber extraction moved on from New England, to the Lake States, the South and finally, the Pacific Northwest. By the 1870s, the removal rates were so high that extrapolation indicated the distinct possibility of a timber famine by the 20th century. By the turn of the century there was a realization that the forests were finite and unlike the Mediterranean experience strong political initiatives were taken to correct the situation. This resulted in a spectacular reversal, which was greatly aided by fundamental changes in the nature and magnitude of wood demand. Fuelwood was largely replaced with other forms of energy, and there was a major reduction in the volume of timber required for railway construction.

Although sustained yield principles were applied to the management of virgin forests, there was an inevitable transitional time lag between the cutting of the old-growth and the time when the new forests would become operative.

2.4 Assessment

The differing histories of the two regions underscores the need for appropriate forest management policies and practices, underpinned by cooperation between government and industry; an efficient and transparent stumpage pricing system; and strong control measures to avoid excessive and unsustainable exploitation. While the message from the Mediterranean case is bleak, the United States experience demonstrates that even after severe exploitation, a forest resource can be recovered if timely corrective action is taken. It is

noteworthy however that the transition from destructive exploitation to a more balanced resource management system required a century to complete.

3.0 GLOBAL FORESTRY IN THE 1990'S: AN OVERVIEW

3.1 Distribution of forest resources and industrial roundwood production

Of the total global forest cover of about 4 billion ha, some 2.8 billion ha are classified as "closed forests". Of this total about 2.2 billion ha are estimated to be of potential as commercial forests. (World Bank 1988).

Forest areas are divided in approximately equal areas between tropical and temperate zones and between industrialized and developing countries. Forests of the developing countries are 90% non-coniferous whereas the forests of industrialized countries are mainly conifers.

In 1997, world production of roundwood totaled 3.4 billion m^3. Of this, fuelwood and charcoal accounted for 56 percent. The balance of 1.5 billion m^3 was used for industrial purposes.

Of the total production of industrial roundwood (IRW), two thirds consisted of conifer species, and one-third non-conifers.

In the global context, there is poor correlation between the existence of major forested areas and the production of IRW. As Sedjo (1990) has noted, "most of the world's forests are not important industrial wood suppliers". About two-thirds of the total resource is located in North America, Latin America and the area of the former USSR. This concentration is even more pronounced for conifer species, which account for 40% of the total forest area. About 80% of the world's conifer resources are located in North America and the former USSR. Although non-conifer forests are more broadly distributed, the primary concentrations are in the southern hemisphere, with Latin America alone having more than 40% of the total.

3.2 IRW production

Unlike the distribution of the global forest resource, the pattern of IRW production is heavily skewed to the industrialized countries of the northern temperate zone, which produce about 80% of the global total (Table 1). Furthermore, this share is heavily concentrated in North America (40%) and Europe (25%).

Table 1. Industrial roundwood production (million m^3)

Region	1970	1980	1990	1998	%/yr 1970-1990	%/yr 1970-1990
Africa	40	51	58	69	2.2	1.2
North/Central America	439	489	594	618	1.2	1.5
South America	39	86	110	130	4.4	5.3
Asia	172	233	262	262	1.5	2.1
Oceania	20	28	33	41	2.6	3.7
Europe	268	282	339	296	0.3	1.2
Former USSR	299	278	305	116	(3.3)	0.1
World Total	1,277	1,447	1,701	1,532	0.6	1.4

Source: FAO Data

The production of IRW has increased steadily for most of the post war period. Since 1961, when global data were first compiled, production has increased by 50% from about 1.0 billion m^3 to 1.5 billion m^3 in 1998. Production reached a peak of 1.7 billion m^3 in 1990, reflecting an annual growth rate of 1.8%. In 1991, world production declined to about 1.5 billion m^3 and has remained at that level throughout the decade. This discontinuity is primarily due to the economic dislocation of the former USSR. Whereas production levels averaged about 300 million m^3 during the 1980s, a severe downturn occurred in 1992 and production levels in subsequent years have only been about one-third of those recorded in the preceding decade. The region's share has fallen from 18 percent of the world total in 1990 to about 6 percent at present.

Sixty percent of IRW production is in the form of saw and veneer logs. The balance consists of pulpwood (30%) and poles and posts (10%).

3.3 Consumption

Developed countries, with only 25% of the worlds' population, currently consume about 75% of the IRW produced globally.

North America, with 39 percent of total consumption, Asia (21 percent) and Europe (20 percent) account for 80 percent of the world's IRW consumption. It is important to note, however, that since 1990 there has been a major reduction in the former USSR, which effectively reduces world total roundwood consumption by about 12 percent, and thus distorts short-term growth rates.

3.4 Trends

During the past two decades, a number of trends have become evident, each of which has either a direct or an indirect impact upon the evolution of the distribution of global industrial forestry. In aggregate, these trends characterize a period of transition, as global forestry moves increasingly from a total reliance on old-growth, natural forest stands to resources based on both reforestation and afforestation in the form of high yield plantations.

3.4.1 Supply

- *Societal attitudes.* The public perception of forests is changing from a tacit acceptance of natural forests as single purpose, industrial resources to a perception of forests with a multiplicity of values.
- *Policy.* Responding to changing attitudes, policy changes are "profoundly affecting timber supply today" (Apsey & Reed 1996). The overall impact is one of continuing pressure to lower the extent and rate of harvest from natural forests. This is particulary evident in the major conifer producing regions of Western USA and British Columbia.
- *High value non-conifers.* Increasing pressure on supply as over-cutting in key producing regions of Indonesia and Malaysia flows through the system.
- *Plantations.* While native forests still dominate global supply, plantation-grown wood is gaining in importance and is estimated to account for 17% of total IRW supply (Hagler 1998).
- *Non-traditional supply sources.* High-yielding, fast-growing plantations in the southern hemisphere are becoming increasingly significant in the global IRW supply mix.
- *"North-south" shift*. The emergence of industrial plantations in several South American countries, Oceania and Indonesia is having an impact on global wood supply. Although IRW supply is still dominated by northern industrialized countries with 90% of the total, there is a discernable "north-south" shift. Taking the aggregate of South America and Oceania as a proxy for "the south", the southern share of IRW production has increased from 4.3% in 1961 to 11.2 % in 1997. Not only is this a high rate of growth, in absolute terms the increase of 125 million m^3 over this period is significant in that it represents 25% of the *increase* in global production over the same period.
- *Wood characteristics.* With the decreasing availability of old-growth forests as harvest volumes from old-growth, natural forests are reduced, there is an accompanying reduction in the diameter and quality of saw and veneer logs.

3.4.2 Consumption

- *Differential growth rates -- regional.* Although industrialized countries dominate the consumption of IRW and wood-based products, accounting for 71% in 1998, this share has steadily declined from a level of 87% in 1961. This reflects the higher population growth rates of developing countries, many of which have significantly higher consumption growth rates, and the maturing of sawnwood markets in industrialized countries. World growth in IRW consumption averaged 1.1% annually between 1961 and 1998. However, during the same period, consumption growth averaged 3.2% in developing countries and only 0.6% in developed countries.
- *Differential growth rates – log end-uses.* Since 1961, sawnwood consumption has grown at an average annual rate of 0.6%. During the same period, pulp and paper consumption grew at a rate of 3.6% annually. For the ten years ending 1998, sawnwood consumption declined by an average of 0.9% annually whereas pulp and paper grew at 2.6%. These product consumption rates are reflected in the consumption rates for the basic roundwood log classifications (Table 2). Pulpwood growth is significantly lower than that of paper mainly due to the impact of recycled paper.

Table 2. Global consumption rates –average annual percentage growth

Period	IRW	Saw/veneer logs	Pulpwood
1961-1998	1.1	1.0	1.9
1961-1991	1.4	1.2	2.3
1988-1998	(0.9)	(0.8)	0.4

The decade of the 1990s saw two major 'discontinuities' in the long-term trend lines for wood consumption. The virtual collapse of the resource economy of the former USSR region has been noted previously. The latter part of the decade included the severe economic downturn in Asia, which reduced demand for all forest products and disrupted trade (FAO 1999). The combined effect of these two factors is reflected in the negative growth rates recorded for the decade ended 1998, which in turn dampened the long-term growth rates, as shown in Table 2.

Hagler (1998) has estimated that manufacturing residuals from sawmills and plywood mills account for 30% of the global usage of wood fiber for pulp and paper manufacture. While greater use of manufacturing residuals is anticipated (FAO 1999), the differential growth rates between paper and sawnwood consumption rates is significant in that it suggests a shift to the increased use of roundwood for pulping in the long-term.

3.4.3 Technology

Historically, technological developments have steadily lowered the unit consumption of wood, with improvements in processing efficiency, product design, the use of manufacturing residuals and recycling all having a significant impact on the volume of wood consumed. Sedjo & Lyon (1990) concluded that it was reasonable to assume, based on long-term trends, an average annual rate of improved efficiency through technology of between 0.5% and 1.2%. Binkley (1994), in noting that the rate of technical improvement is difficult to measure, suggested that the trend probably lies in the range of 1 to 2 %/yr for many wood products manufacturing operations. Both sources point out that technological improvements reduce the amount of IRW required to produce a given volume of product. The more significant developments in recent times include:

- *Plantation forestry*. Advanced technologies are of increasing importance in plantation forestry. As Kanowski (1997) notes, biotechnology applications in the production and propagation of interspecific hybrids is of particular interest. The optimal integration of biotechnologies with plantation forestry is program-specific. Yield and quality improvements have been significant in some instances, and the potential for further improvements is promising.
- *Engineered wood products and reconstituted wood panels.* The declining availability of large diameter, old-growth trees has provided an incentive for industry to develop products more suitable for smaller diameter and generally lower quality roundwood. This has given rise to "reconstituted wood" panels, most notably OSB and MDF, which use small particles of wood

mixed with resin. Physical properties designed to meet specific end-uses are "engineered" into the panel giving it superior performance characteristics.

- *Substitution*. Technological adaptations and improvements have enabled the substitution of non-conifer species for conifers in the fiber furnish of many paper products. This has in turn enabled non-conifer plantation wood to gain in significance as a pulping fiber.
- *Wood products processing.* Much progress has been made in the ability to process smaller diameter logs for both sawnwood and plywood. These developments ease the transition from larger logs to smaller logs, which is common in most supply regions. In fact, the traditional "definitions" of log categories is becoming increasingly blurred (Hagler 1997). The ability to process smaller diameter logs greatly facilitates the transition to plantation wood.
- *Recycled paper*. While the recycling of paper is a long-standing practice, the sharp increase in the past few decades has been dramatic. In 1970, the global utilization rate was 18%; by 1988 this had increased to 32% and the rate is currently in excess of 40%. This trend has had a major impact on the volume of wood fiber required for paper manufacture.
- *Pulping*. There has been a steady evolution of the basic pulping processes, resulting in reduced emissions and reduction of unit consumption levels for wood fiber, energy and, in the case of chemical pulp, water. These developments ease the constraints on mill location (i.e. less water and external energy required) giving the potential for capacity developments in previously unworkable locations.

3.4.3 Industry structure

- The forest products industry globally is noted for its high degree of fragmentation. It is characterized by a large number of players, none of whom has dominance either regionally or by product group. The degree of fragmentation varies by product group and by region and is driven by processing technologies, scale economies and access to wood supply and markets.

- Sawmilling is a major consumer of IRW in all countries with a commercial forestry resource. Sawnwood manufacture at its most basic level is a simple process and not capital intensive. Consequently, it has traditionally been an "easy entry" activity. This has led to a proliferation of small mills and companies, particulary in the developing world. For example, Argentina is estimated to have about 3,000 sawmills with an average wood input of about 1,000m^3 annually (CINTRAFOR). Similar patterns are found throughout Latin America and Asia. These small mills, which tend to be very inefficient users of IRW, are usually located near the forest resources, and serve local markets. By contrast, in industrialized countries sawmilling has evolved into a sophisticated and highly efficient processing industry. Mill outputs vary greatly, ranging from relatively small mills with wood requirements in the order of 100,000m^3 annually to mills consuming several times this volume.

- There is a much greater degree of concentration within the pulp and paper sector, which is capital intensive and constrained in terms of flexibility with respect to scale by the nature of the basic processes. Technical and economic factors dictate that chemical pulping, the dominant process globally, be sized to consume in the order of one to two million (or more) m^3 of wood fiber annually. These criteria apply regardless of operating region. Thus, for example, Brazil and Indonesia have some of the world's largest pulp mills.

- There is a marked trend to corporate concentration. In 1997, the top 100 companies processed 50% of the world's IRW. However, within this grouping, the top 10 companies consumed 20% of the world total (WWF 1999). By contrast, in the late 1970s the leading 20 companies accounted for about 20%. This trend is driven by the need to improve financial performance through scale economies and rationalization. As a commodity oriented business, forestry operations are increasingly seek to position themselves as low-cost producers. Since wood cost is a key factor in the manufacture of basic forest products such as sawnwood and pulp (typically in the range of 40 to 60% of operating costs), there is an increasing interest in identifying those strategic directions that will result in relatively low wood costs.

OVERVIEW OF KEY PRODUCING REGIONS

1.1 Introduction. In order to develop an appreciation of the outlook for the supply/demand balance of IRW globally, it is important to attempt to understand:

- The extent to which the main producing regions can maintain and/or expand their output and,
- The extent to which those regions that appear to have significant under-utilization of their industrial forests can reasonably be expected to realize their apparent potential.

Each of the main producing regions is reviewed briefly in the following paragraphs. It is emphasized that the scope of this discussion is very large, and only a brief synopsis for each of the key regions is given here.

1.2 North America. The world's most important wood supply region, with more than one-third of global output, is likely to maintain its dominant position in the foreseeable future. However, the entire region is in the throes of a major wood supply transition, precipitated by the combined effect of harvest levels reaching – or exceeding – sustainable levels in the West, and of increasingly intensive environmental and land-use pressures throughout the region. While there is some limited scope for the expansion of harvest levels from natural forests in some areas, particularly of non-coniferous species, harvesting costs and environmental pressures are constraining factors. On balance, the outlook for the natural forest from the stand point of IRW is one of a static or even declining production forest area.

The main potential for significant expansion of the industrial forest lies in the development of fast growing plantations in the southern United States region, which has been described by Zobel (1984) as the "wood basket of the world". The net annual increment for the southern US has recently been estimated to be in the order of 270 million m^3. Current harvest levels represent about 40% of the North American total, and 15% of the world total. However, the ability to exploit the full potential is problematic. Conifer harvests exceed growth, private landowners are only partially interested in growing timber of industrial use and environmental constraints are increasing (Cubbage 1997). As Hanson (1999) has noted, in the absence of improved forest management in the region, the harvest level from the south is likely to be flat or even decline, and log quality will deteriorate.

Canada's IRW production accounts for 30% of the North American total, or 10% of the total world harvest. Unlike the US, the bulk of the resource is still in old-growth stands. In the west, two thirds of British Columbia's forests are mature stands of old-growth. During the past two decades, the annual allowable cut has bee reduced from 90 million m^3 to 72 million m^3 with the likelihood of further decreases in the near future.

Compounding the difficulties resulting from inadequate regeneration and a constrained output relative to the limitations of sustainable growth, the Canadian industry, particularly in British Columbia, is facing continuing pressure from environmental groups. These pressures have already resulted in significant reductions in commercial forest concessions and are a manifestation of the mounting debate with respect to the broader definitions of the economic and social value of forests generally.

Overall, the prospect for North America is one of increasing tightness in IRW supply, despite a theoretical surplus of annual increment to production levels.

1.3 Europe. Although forest growth presently exceeds removals, Europe, including Eastern European and Nordic countries, but excluding the former USSR, is the world's second largest IRW producing region. Of the total industrial output of 300 million m^3, one third is from the Nordic countries, 12% from Germany and 10% from France.

As a region, Europe is presently in a surplus wood position, with annual growth outstripping supply. However, although growth still exceeds removals, the potential for continued expansion is limited and exacerbated by the impact of air pollutants and a reduced emphasis on production forests in favor of multiple-use forest management (IIASA 1991).

Apsey and Reed (1995) concluded that the combined IRW production in Western and Eastern Europe would increase at an effective annual rate of 0.6% to 2020.

On balance, while European wood supply is presently in a surplus position, the expectation is that further increases in available wood harvest will be relatively modest. The long-term outlook is one of increasing pressure on the existing forest base in supplying the region's industrial wood requirements.

Former USSR
The forest resources of this region are vast, accounting for 25% of the world's exploitable closed forest area and more than 55% of the growing stock of conifer species. Given the region's large population, its large surplus of conifers, and its geographic proximity to Europe and Japan – two of the world's major wood consuming regions – it is not surprising that it is considered by many to be a key factor in the global supply/demand balance of IRW.

The huge forest resource and an estimated surplus more far in excess of present production levels do not ensure a commensurate increase in production. The main body of the forest resource is not well located relative to the principal consuming regions and there are many technical, environmental and economic constraints to be overcome before significant increases to present harvest levels could be realized. In actuality, that portion of the region's forest resource which is within reasonable access to the main population centers has been over-cut, and extensive plantations have been developed to help redress the resultant supply-demand imbalance.

The IIASA research team of Nilsson and Shvidenko (1998) state that Russian forestry has essentially followed a "mining" approach. The team notes "the quality of Russian forests was seriously impoverished between 1961 and 1993 with a decrease in the extent of valuable tree species, decreased tree sizes, and regional over-harvesting".

Nilsson and Shvidenko estimate the economic sustainable supply of IRW to be in the range of 160 to 290 million m^3, based on a stable harvest over the long-term. They note, however, that a more rapid liquidation of mature forests could add annual volumes in the order of 90 million m^3 over the next 40 years. The restructuring of the region's forest industry will be difficult and costly, and require foreign involvement.

Japan
Japan is a major factor in the forest industry internationally, ranking in the top three countries in terms of consumption of forest products, and is also one of the world's leading producers. Although nearly two-thirds of the country's land surface is forested, of which about 40% is in plantations, Japan is not self-sufficient in IRW production. Although Japan's resource base is sufficient to support an increase in the country's self-sufficiency level, this potential will continue to be seriously constrained due to the high wood costs resulting from fragmented ownership, scarce and costly labor, difficult terrain, and mounting environmental and land-use pressures.

Japan provides a good example of the gap which can exist between potential physical levels of IRW harvest and those which are socially and economically viable. The country is likely to continue to be a major importer of fiber in the foreseeable future.

China and India
China's IRW production is currently about 110 million m^3, or 40% of the Asian total and five times that of Japan. Wood harvest levels have increased significantly in recent years, having grown steadily from 35 million m^3 in 1961-an annual growth rate about three times the global average for the same period. This growth rate is unsustainable, and there has been a leveling off during the 1990s. A growing timber shortage over the next several decades is expected by CINTRAFOR (1999).

Plantations offer the only opportunity China has to significantly increase its wood production over the long-term. Even if current planning targets were to be met, the fact that climatic conditions in most of the country are unsuitable for fast-growing plantations means that there will be increasing pressure on the

existing supply base for several decades at least. Much will depend on the survival rates and actual yields of the planting program.

With an annual IRW output in the order of only 25 million m^3 (not much greater than New Zealand's), India's situation is one of extreme scarcity. As in the case of China, the country's IRW production can only be improved through planting programs. Given that the combined population of India and China is about 40% of the world total, only massive planting programs could have any significant impact on the per capita levels in both countries.

Malaysia and Indonesia

Indonesia and Malaysia have long been the dominant suppliers of tropical logs and products. However, as noted by Jaakko Poyry (1997) and others, the IRW output of these countries is expected to decline dramatically. Both have announced harvest reductions which in aggregate total 45 million m^3 (ITTO 1996). In an analysis of the supply situation in both countries, Blakeny (1997) notes that land conversion is the biggest threat to sustainable forestry. Large areas are being converted to agriculture in both countries, which is reducing the land base for production forestry. Furthermore, past harvesting has reduced growing stocks of commercial tree species in the remaining native forests, resulting in the prospect of continuing decline in harvests. Blakeney notes that for both countries combined, the 1996 harvest of native species was 66 million m^3. As the sustainable total harvest is estimated to be only 35 million m^3, a reduction of about 30 million m^3 is projected by 2010. These declines will not be offset by short-rotation pulpwood plantations, which cannot substitute for high-value saw and veneer logs. Long-rotation plantations of native forests will not have significant impact early enough to offset declines.

Oceania

With an IRW output of about 40 million m^3, Oceania accounts for only 2.5% of the world total. Ninety percent of the region's output comes from Australia (20 million m^3) and New Zealand (16 million m^3). Both countries have a surplus of IRW (about 15 million m^3) that is expected to increase over time as plantations continue to mature. While Australia's IRW output has been about evenly divided between native and plantation forests, New Zealand is 95% dependent on plantations. Australia has announced an ambitious plantation development plan, adding two million ha to its existing base of about one million ha by 2020. New Zealand has large volumes of maturing plantation wood coming on stream during the next decade, and continues to add to its plantation area.

South America

Despite having 25% of the world's area of closed "commercial" forest, South America's 1997 output of IRW at 130 million m^3 was only 8% of the world total. Brazil dominates, accounting for 65% of the region's total IRW output, followed by Chile with 15%. The remaining 20% is spread between 11 countries.

Since 1961, South America's IRW production has grown at an average annual rate of 4.2%. This long-term rate is heavily weighted by exceptionally high growth during the 1970's, when the average rate was 8.2%. In the 1980s, the rate declined to 2.3% and the 1990s have averaged only 1.7% growth to 1998.

Brazil and Chile together accounted for almost 80% of South American growth in IRW production since 1980, with Brazil supplying over half the total.

About one third of South America's land area is forested, resulting in a huge surplus of growth relative to harvest levels. However, the theoretical surplus bears little relationship to the practical realties, which derive from social, technical, and economic considerations. The remaining native forest, located mainly in the Amazon basin, is remote and extremely heterogeneous. These technical and economic constraints are increasingly likely to be secondary to the continuing domestic and international pressure to conserve the tropical forests and to avoid land-use conflicts arising from industrialization.

In terms of future prospects, the defining characteristic of South American forestry is the established base of high-yield plantations and the potential for further increases to this base. Since 1986, Brazil's IRW harvest from native forests has declined by about 50 million m^3. During the same period, the volume of

wood harvested from plantations increased by more than 60 million m^3. Since the discontinuance of Brazils' plantation subsidy program in the mid-1980s, plantation establishment rates have fallen off. The supply of Brazilian saw and veneer logs will come under increasing pressure in the medium to long-term. Analysis by both Donnelly (1996) and Tomaselli (1997) suggests that the Brazilian plantation system is close to its effective limit relative to "trees in the ground". The Brazilian Society of Silviculture (cited in a 1997 ITTO report) has estimated that an additional 500,000 ha /yr of plantations are required to support the potential expansion of the country's industrial sector.

Chile has developed a major plantation resource. Begun in 1940, the plantation estate is now about 1.5 million ha. Current IRW production is in the order of 20 million m^3 or about the same as Australia's and about 25% greater than New Zealand's. With its relatively small population, Chile is in a strong surplus position and is likely to remain so. This has enabled the development of a strong processing and export sector.

In recent years, Argentina and Uruguay have experienced strong growth in the development of fast-growing IRW plantations. With their relatively small domestic markets, both countries will have increasing opportunities for export.

In discussing the South American IRW supply region Tomaselli (1997) notes, "the rate of expansion of forest plantations in the region tends to be lower that the growth in demand for wood fiber, and as a result prices are expected to increase in the region". He also makes the point that "paradoxically, land availability can be a limitation in quite a number of the countries in the region".

Africa

Although the African continent has a significant theoretical surplus of net annual growth to production in native forests, this does not translate into a realistic potential for significant expansion over the long-term. South Africa is the leading African producer of IRW with a current output, based almost entirely on plantations, similar to that of Chile and New Zealand. Although South Africa's fast-growing plantations are among the most successful in the world, further expansion is hampered by the availability of suitable land.

There is biological potential for substantive development of IRW plantations in many other African countries, several of which have long-standing plantiong programs. In the past, development has been constrained by a variety of factors, including political instability, inadequate infrastructure, lack of capital, skill shortages, land-use conflicts and access to markets. While many, if not all, of these constraints can in theory be removed, the time required to realize such a transition is indeterminate.

GLOBAL SUPPLY /DEMAND BALANCE

The world's forest industry is becoming increasingly global. While international trade has played an important role throughout its history, the industry is currently undergoing a transition which is increasing the importance of trade, and at the same time, shifting the traditional patterns of trade.

New supply regions such as Chile and New Zealand are becoming increasingly important suppliers to many countries as their plantation resources reach maturity. Scandinavia, a longtime traditional supplier of European markets, now has a surplus of wood and is able to competitively ship manufactured products to Japan in direct competition with British Columbia and the Pacific Northwest of the United States.

Plantation wood is expected to play an increasingly important role in the domestic supply of many countries, and as a new supply source for deficit wood-supply regions. At the same time, wood availability from many traditionally important regions either has reached its limit or is in decline--as is the case for conifers from British Columbia and tropical non-conifers from Indonesia and Malaysia.

There is an increasing interdependence of regions in surplus and those with a deficit. Product prices are increasingly set by international benchmarks, and few if any regions can function in isolation.

Review of recent global supply-demand outlook studies

There has been a mounting concern, in both the public and private sectors, regarding the ability of the global forest resource to meet long-term demand requirements. This concern has resulted in several studies and papers by many of the world's leading forest economists. This section of the report presents brief reviews of the salient points of the most prominent and current of these reports.

1. World Timber Resources Outlook--Current Perceptions. Apsey and Reed (1995)

After analyzing the supply potential in 33 countries the authors then aggregated the supply projections and compared these against the projected demand for industrial roundwood. The result of this analysis showed a large and widening "gap" between supply and demand to the year 2020.

The authors conclude that their analysis foreshadows "local and regional timber deficits of serious proportions". Volume shortages alone do not disclose what may be a major loss of high quality saw and veneer logs, sharply higher roundwood prices, and important shifts in regional shares of the global market.

2. Monitoring the Global Wood Fiber Equation. Seminar by Wood Resources International Ltd. (1997)

The principal findings were:

- Global timber supply, while projected to increase, will not keep pace with demand growth over the forecast period 1995-2030.
- The most significant increases in supply will be in Latin America and Asia.
- Plantations will increase in importance as a fiber source, increasing from about 17% to approximately 340% by 2030.

3. Solidwood Products Competitiveness Report. A study for the American Forest Products Association by Jaakko Poyry (1996).

The study concluded that continued population growth, increasing per capita fiber consumption, and the mounting pressures for alternative land values from timber lands globally will lead to fiber supply and demand discontinuities, despite an increasing role for plantation wood. Major changes will be needed to meet future demand. Increased harvesting in Western and Eastern Europe, the Nordic countries and from Southern hemisphere plantations will make up expected shortfalls.

4 Long-term trends and prospects in world supply and demand for wood and implications for sustainable forest management. Solberg, Brooks, Pajuoja, Peck and Wardle. (1996)

The study noted that while the long-term outlook is for steadily rising demand for wood and the services of forests, there is an accompanying expectation of a declining area of forest available for these products and services. As pressure on supply mounts, product prices will increase, resulting in an increasing intensity of forest management (as also predicted by Sedjo, Jaakko Poyry and others). While the outlook for demand and supply of wood does not suggest a crisis, it does indicate that active management of forests globally is a necessary development.

5. FAO

(a) State of the World's Forests. (1997) And (1999)
(b) Provisional Outlook for Global Forest Products Consumption, Production and Trade to 2010 (1997)
(c) Global Fiber Supply- (1999)
(d) The Potential Role of forest Plantations in Meeting Future Demands for Industrial Wood Products. Whiteman and Brown (1999)

Whiteman and Brown report on the output of the FAO supply and demand models and the forecasts to the year 2010. The authors have extended, with some caveats, the forecasting models out to 2050 in order to examine the likely contribution that IRW plantations might make to global supply over the long-term. They conclude that forest plantations will account for about one third of IRW supply by 2010 and will continue to increase their relative position depending upon establishment rates. Three planting rate scenarios are postulated. The range of potential supply form plantations by 2050 is broad, from 600 million m^3 to 1.4 billion m^3, underscoring the importance of planting rates to projections of future supply.

6. The Long term Adequacy of World Wood Supply-- Sedjo and Lyon. (1990 and 1996 for IIED)
In 1990, Sedjo and Lyon published the results of an interactive global timber supply model. In 1995, the model and its database were updated to assist IIED in its examination of global pulpwood supply. The model output suggests that future demand (for the projection period to 2045) could be met, subject to the following conditions:

- 15 million hectares of new tree plantations established in the southern hemisphere,
- no constraints imposed on the supply system beyond those already in place,
- demand growth averages one percent annually.

The total production of industrial wood is projected to increase to 2.3 billion m3 in 2045. Prices increase in real terms over the period, signifying a "tightness" in supply.

7. Do We Have enough Forests? Nilsson (1996).
In analyzing timber supply, Nilsson concluded that:

> "All signs indicate that we do not have enough forests on the globe to fulfill all the current and future demands on global forests. There may not be a physical shortage of forests, but the different kinds of demands will be difficult to meet."

Two regions will hold the key to the balance of industrial roundwood. He contends that southern hemisphere plantations are "crucial to balancing the global supply of non-coniferous fibers", but that many questions remain regarding the outlook for these plantations. Russia holds the key to long-term conifer supply, however there is still much uncertainty as to when - and whether - the country will be able to develop its enormous resource base.

8. H. A. Simons -- Global Timber Supply and Demand to 2020. (1994).
The Simons report predicted that throughout the forecast period (to 2020) global demand for industrial roundwood will exceed the *available* supply. The first supply deficits will to occur in non-conifer saw logs at the outset of the 21st century, initially in Asia and Latin America. In order to alleviate the impending supply pressure in saw logs, the existing plantation base would have to be larger than the actual area at the time the projections were made. Although the market is likely to respond with increased plantation investment, the longer growth period for saw logs will delay the effective supply response time

9. Journal Articles - Various
Several papers addressing global fiber supply have been published in professional journals in recent years.

Lyle and Brooks (1995) of the US Forest Service forecast a scarcity of preferred species (especially non-conifers) and large, high-grade logs.

In assessing the future of fiber in "tomorrow's world", McNutt and Rennel (1997) point out that except for new fast-growing plantations, the trees needed to meet virgin fire demands for all forest products to 2010 and beyond are already growing. They conclude that although in global terms there will not be a long-term fiber shortage, supplies will tighten within and across regions - particularly for boreal conifers and native non-conifers, and for large dimension logs of all species.

In an earlier article, McNutt (1996) concluded that neither moderate nor aggressive projections for supply increase come close to matching anticipated demand.

McNutt states that the emerging role of plantations as a fiber supply source requires careful examination. He concludes that while the yield from fast-growing plantations will meet a portion of predicted future roundwood requirements, the volumes available will not overcome the long-term worldwide timber supply/demand discontinuities.

In a paper titled "Adapting to global supply constraints--or: timber famine and six reasons why it won't occur", Binkley (1994) suggests that the inevitable increases in population and wood consumption, against an acknowledged decline in traditional timber supply, will result in price increases. He believes that the physical depletion of timber, conversion of forest land to other uses and environmental restrictions on

timber harvesting in the remaining forested areas will limit further timber supply from regions that have traditionally produced much of the world's timber. Fast-growing plantations established in the low and middle latitudes will not fully offset the reductions in timber harvest in the traditional supply regions. However, rising demand and limited supply will induce a variety of adaptive responses. In the longer run, higher timber prices will provoke new plantations and more intensive timber management.

Consensus

Several common themes are evident in the preceding studies and papers.

- All sources are unequivocal in predicting the continuing growth in wood products consumption, and of industrial roundwood production to support this increase. While there is a fairly wide range of projected average annual growth rates, the mainstream range is in the order of 1.0 to 1.5 percent.
- Demand growth will not be evenly distributed across regions and nations. While the developed world will continue to consume the bulk of wood products and roundwood, growth rates will be relatively modest, reflecting maturing markets. Conversely, developing economies are expected to show the highest consumption growth rates for all basic product groups.
- Supply of timber from traditional sources will be constrained, relative to biological potential, in most regions. The reasons for this cover a broad spectrum: past over-cutting (relative to sustainable volumes) in countries such as Indonesia, Malaysia and Canada; environmental pressures resulting in altered harvesting practices and forest area set-asides; competing land-use pressures; urbanization; lack of infrastructure in remote regions; and the inability to achieve acceptable economic returns within the range of prices experienced to date.
- The supply of large diameter logs of qualities suitable for saw and veneer logs will continue to decline.
- Prices for industrial roundwood will increase, in real terms, over the long-term, reflecting a relative scarcity of material.
- All forecasts and predictions for future supply explicitly assume continuing investment in fast-growth plantations and intensive forest management for second-growth natural forests. The extent to which either of these enhancements to the global wood supply base can be implemented in a timely and effective manner is not well addressed.
- Several sources referred to the expectation of increased international trade in products and roundwood, as regional imbalances become increasingly severe.
- There is a range of outlooks with respect to the long-term supply-demand balance of industrial roundwood. The more pessimistic of these foresee the development of increasingly severe pressure on supply, with the prospect of "gaps" of supply relative to projected demand. The more optimistic outlooks foresee supply meeting demand *globally*, but with regional imbalances.

Data inadequacies

Most of the authors of the preceding works decried the inadequacy of data with respect to supply. In particular:

- Inventories of standing timber are either incomplete or unreliable in many regions.
- Information relating to plantations is also weak. The actual annual rate of plantation establishment, particularly in terms of net planted area by species, yield category, end-use type and region is not well established.
- The extent to which intensive forest management is actually being successfully practiced in second growth natural forests is not well documented.

Assessment

The overall long-term global outlook is for increasing demand against a tightening (at best) supply capability, and increasing prices. Regional discontinuities will be magnified, reflecting growing deficits in some regions and potential surpluses in others, thus leading to increased international trade. There will be a decrease in the global supply of large saw logs and veneer logs, and log quality will also decline. There is a strong consensus of expert opinion that the southern hemisphere will play an increasingly important role in the global supply of industrial wood. In order to meet projected global wood requirements in the face of

constrained supplies in many of the traditional supplying regions, there will need to be a continuing investment in new plantations.

6.0 STRUCTURAL CHANGE IN THE LONG - TERM

6.1 Introduction

History has shown that the evolution of forestry has been marked by periods of transition, and that such periods have often experienced major problems of forest resource management and use. The evidence at hand suggests that global forestry is presently undergoing a transition, albeit at different stages regionally. The trends in supply signal a lessening reliance on old-growth natural forests to wood supplied from intensively managed resources based on reforestation and afforestation. In particular, there is a significant move to high yield IRW plantations in the southern hemisphere.

While the pace of change during the next 50 years is unlikely to diminish, it is impossible to predict with any certainty the nature of the industry by 2050. One has only to recall the major changes that have occurred in North America alone during the past 50 years to invoke the cliché "the only certainty is uncertainty".

That said there are some indications of the likely *direction* of change and of the underlying forces. The more important of these will be briefly reviewed in the following section. It is stressed that the overall global situation is one of great complexity, with regional differences and linkages.

6.2 The wood requirement

Assumed demand. The project team has reviewed the various long-term projections of IRW consumption, and to establish a common reference point has assumed that world consumption in the year 2050 will be 2.5 billion m^3. This implies an average annual growth rate of about one percent, which is consistent with the long-term historic trend. Clearly, this is a critical assumption as small variations in the assumed annual growth rate translate into very significant absolute numbers 50 years on. Thus, for example, a rate of 1.3% would result in an increment of 800 million m^3 over the assumed 'base case' consumption for the year 2050. If nothing else, such sensitivity suggests the need for great flexibility in long range planning.

Volume increment. Given the current usage level of 1.5 billion m^3, the indicated annual IRW supply increment by 2050 is about one billion m^3. If the long-term (1961-1998) growth rates of log classifications by major end-use category were to hold over time, this incremental requirement would comprise approximately 1.3 billion m^3 of saw and veneer logs, 1.0 billion m^3 of pulp logs wood and 200,000 million m^3 of logs for other uses. While these numbers can only be taken as being broadly indicative of the long-term situation *were past trends to continue*, they do underscore the continued, if relatively lessened, importance of saw and veneer logs in the overall mix. This has important implications for IRW supply scenarios, given the current decline in saw log material from traditional supply sources, the longer rotation age requirement for plantation-grown saw logs compared to pulpwood and the focus on pulpwood in major plantation developments in recent years.

6.3 Technology

Importance. Technological developments have been a key factor in determining the volume and characteristics of global IRW consumption and production, as outlined in an earlier section. While there is no reason to doubt the likelihood of further improvements over the next 50 years, it is impossible to be specific as to the rate or extent of change.

Evolutionary development.: A continuation of trends already in place is likely in the following areas:

- -Upstream: yield and quality improvements, the application of intensive management techniques to high value hardwoods, the adaptation of plantation grown species (such as eucalyptus) for high-value saw and veneer logs
- Downstream: New techniques for processing small diameter logs into wood products, further substitution of non-conifer species for conifers, development of composite products, improved processing efficiencies for all products.

Breakthrough technologies. Over the course of fifty years, there is a reasonable probability that one or more major breakthroughs will be discovered. Although efforts have been made for many years to develop an alternative for the capital intensive and scale-sensitive chemical pulping process, it is still dominant, accounting for about 70% of all pulp manufacture. High-yield mechanical pulping, which uses roughly half the wood fiber per ton of pulp, provides an indication of the potential scope for significant impact although it is limited as to end-use applications. To date, there is no indication of any realistic replacement for the chemical pulping process, and any major change is likely to occur nearer the latter part of the planning period and thus have a minimal impact on overall wood consumption volumes.

Technologies which enable the utilization of small logs for wood products rely on adhesives. Since conventional adhesives are derivatives of petroleum products, they are likely to face increasing costs over the long-term. Much research has been done to utilize the tree's natural "binder" (lignin). The science involved is complex and commercially viable developments, if any, will probably require many more years of research.

6.4 Forest management

At the outset of this paper, Mather (1993) was cited in describing the transition form old-growth forests to more intensely managed forests as a defining feature of the 20th century. He also noted that major problems of forest resource use occur at times of transition. Mather's cautionary observation resonates in the differing views with respect to appropriate approaches to forest management. This debate is well captured in papers by Binkley (1997) and Oliver (1999) and the issues go to the heart of the global vision hypothesis.

Oliver identifies a gradient of forest management approaches form capital-intensive plantations to unmanaged and unharvested forests. Four approaches are described,

-intensive plantations,
-integrated management,
-incidental harvest,
-reserves.

Oliver notes that a common proposal is to zone areas to plantations, integrated management and reserves. He is critical of intensive plantations, which seek to achieve high yields for a specific end-use application, and are bases usually on mechanization and what he refers to as mass production. According to Oliver, forest management is presently moving in several directions, with some policies encouraging intensive plantations and others encouraging integrated management. He contends that governments will either prohibit harvest of most of the world's forests and adopt intensive plantations on the remaining area, or "promote integrated management through incentives and/or restrictions." Oliver is adamant that unless a clear and consistent policy emerges there could be "confusion in forest management that could last for years".

In Oliver's view, there are two main problems with intensive plantations-high early investment costs and short-rotation, low quality wood. Alternatively, stands could be allowed to develop in a variety of natural patterns, but applied with a variety of silvicultural treatments. A more diverse mixture of wood qualities and species would be provided, with greater flexibility with respect to harvest timing. In addressing the global situation, Oliver compares the two approaches as follows:

> Intensively managed plantations can provide 10 to 40 m³/ha/year of wood volume-ten to forty times the world's annual consumption per hectare. Even more moderate increases in growth of some forests through management could dramatically exceed the world's current wood consumption. For example, intensive plantations providing 12.5 m³/ha/year could provide the world's current wood consumption by growing low quality wood on 8% of the world's forestland. These intensively managed forests would be in highly productive, accessible areas such as the tropics, the southeastern United States, and southeastern Asia.
> Alternatively, forests could be managed through integrated management. If this management grew at 6 m³/ha/year of total wood, the world's current consumption in low quality wood and an equal amount of high quality wood could be provided by managing 33% of the current forest area through a combination of thinnings and final harvest.

Oliver does not favor the allocation of forests into zones, claiming that it would be socially and politically difficult, if not impossible , to displace traditionally wood-producing economic sectors for parts of the world to be zoned as reserves.

An opposing view is presented by Binkley (1997) who makes the case for preserving nature through intensive plantations. He proposes zoning and intensively managed plantations, using the case of British Columbia as a basis for his argument. He claims that by applying more intensive forest management practices to 17 million ha in British Columbia (about 18% of the total land area) yields could be increased by a factor of two or three over those available in unmanaged natural stands. Through a policy of zoning and intensive, dominant-use management, British Columbia "could devote three quarters of the province to sustaining non-timber values of the forest." In his critique of approaches other than zoning and intensively managed plantations, Binkley states that they are based on the assumption that forestland is abundant. He notes that this is not the case, even in British Columbia with its vast areas of forested land.

The resolution of these differing approaches will not be easy, particularly as they likely to vary not only between countries but also within regions in some countries. There appears to be a lack of hard data and comprehensive analysis, with much of the present support for differing approaches based on anecdotal evidence. Overlaying the technical and economic complexities is the attitude of the general public to forest resource use and management.

6.5 Expansion potential -traditional supply sources

For purposes of this discussion, *non-traditional* supply areas are taken to be those which have established short-rotation, high-yield plantations, or that area which in aggregate Sedjo and Lyon (1990) refer to as "the emerging region". Traditional supply sources are assumed to include all other areas. In this context the southern US is considered a "traditional" supply source.

In the context of the required global volume increment over the 50-year period under consideration, the earlier review of supply regions and supply-demand balance suggests that there is very limited scope for significant increases from the traditional supply sources, with the possible exception of:

- Russia
- The southern United States
- Temperate-zone intensive management.

Russia. With a net annual growth of nearly 1 billion m^3 (Nilsson and Shvidenko-IIASA 1998) and a current production leveling the order of only 100 million m^3, Russia is an enigma. Much of the potential cannot be realized for the reasons noted earlier. According to the IIASA research team, Russia's IRW annual harvest has an actual potential to reach a maximum of between 250 and 380 m^3 during the first half of the 21st century. This estimate includes an assumed 90 million m^3 annually from the accelerated liquidation of a portion of the country's over-mature forests. The extent to which Russia's potential will be reached is problematic, at least in the medium term. As Nilsson and Shvidenko point out, the country faces a dilemma. Although external investment is required, the international forest industry is hesitant to become involved in Russia because of the negative investment environment.

Southern USA.

Previous reference has been made to the importance of the southern US as a wood supply region. Its IRW production, of about 250 million m^3, exceeds that of all counties in the world, and is in the order of the total output of both Asia and Europe. The region is the major supplier to the largest consuming market in the world. Clearly, any significant changes in the productive capacity of the southern US can be expected to have a major impact on the global dynamics of IRW supply. During the past decade, the region has proven capable of absorbing the production losses in the PNW. The key question is whether the southern US can be expanded sufficiently to accommodate future demand growth. From the literature, it appears that the answer is a *conditional* "yes". Most observers agree that the region has tremendous potential for increased harvest levels through the application of intensive forest management to the southern pine plantations.

Kellison (1998) points out that the growth rates achieved from the extensive silvicultural system found in the southern pine region average about 7 m^3/ha/yr and 15 m^3/ha/yr for non-conifers. He states that "a great opportunity exists to intensively manage domestic forests on a portion of the land. Tripling productivity is a stretch goal however field trials give confidence that goal can be attained, with yields of 22 m^3 indicated compared to the average yield of 7 on the 11.2 million ha of plantations in the south". The USDA Forest Service, reporting on the results of its model of timber markets and supply (Alig *et al* 1999), states that "private timberlands in the USA have the biological potential to provide larger quantities of timber on a sustainable basis than they do today", noting that most opportunities for increase lie with the private non-industrial timberlands in the South. Other sources echo similar views with respect to the potential.

Given the evidence of tremendous biological potential, it is somewhat of an anomaly to encounter a generally negative cast in most of the literature. As Kellison notes in speaking of the US South, "there is concern that demand will exceed supply, and that a timber famine will occur shortly after the turn of the century". The reason for the general concern lies with the nature of land ownership in the South. The allocation of land and the condition and management of forests in the South is determined by the decisions of a wide variety of landowners who have a wide range of objectives and approaches to forest management. (Wear 1996). In total, the region's land is 90% privately owned, and of this portion, industry owns only 22%.

Particularly pessimistic outlooks are given by Cubbage (1997) and Colberg (1996). Cubbage is skeptical about the region's capability to achieve and maintain projected increases in timber supply. He states that "several studies have shown that in total, various demographic, physiographic, and environmental factors could reduce the actual hardwood timber that is available by one-third to one-half and softwood timber by 10% to 20%. Total economic supply may be considerably less than timber inventory." Colberg notes that while industry is improving yields on its forestlands, the performance of the non-industrial sector is generally poor. He claims that no more than a quarter of the cutover acreage on non-industrial private land is seeded or planted following harvesting

More positively, Hagler (1994) suggests that the region will generally be able to maintain production levels in the years ahead, although it will no longer be a low cost producer. In a more current paper Kaiser (1997) of the USDA Forest Service asserts that "assuming that timberland owners continue to respond as they have in the past to price and inventory changes and manage their private stands as projected, timber harvest from private lands will be increased substantially in most regions". He suggests that for the US as a whole, IRW harvest could reach about 700 million in 2040 (up from about 400 million currently), with most of the increase in the southern US. Reporting in 1999 on a study of private forest investment in the US, Alig *et al* also conclude that there is a substantial potential of timberlands for increased growth and harvest. They differ from Kaiser, however, in that a condition of the realization of this potential is that investments in planting be made at a rate "well beyond those observed in recent years." They state that given adequate investment, the area in planted forests would almost triple within the next 30 years.

On balance, the situation in the southern US is one of considerable uncertainty. While there is a clear theoretical potential, the apparent lack of a common commitment to intensive timber production amongst a large portion of the private timberland owners suggests that any unified response would require a considerable and continued increase in timber prices. While this may well occur in the future, there is a time lag of 25 to 30 years for pine saw logs to reach harvest age, thus extending any real expansion in harvest volumes for a considerable time.

Intensive forest management. In addition to the intensive management of planted or naturally regenerated forests of the US South, there is potential to apply similar growth enhancing techniques to the indigenous forests of much of the temperate zone. Unfortunately, there does not appear to be a comprehensive literature addressing systematic analyses of costs and benefits applied to industrial forestry. In part, this reflects the site-specificity of forestry generally, the long rotation ages involved, and that probably, with the possible exception of Scandinavia, the application of intensive silvicultural techniques to indigenous plantings is apparently not widely practiced. In any event, there is some anecdotal evidence from North America that suggests the potential for significant gains, although the associated costs are not evident.

For example, Michaelis (1993) suggests that with herbicide treatment, two commercial thinnings, and a treatment of fertilizer, an average acre in the US Northwest could produce 40 to 60 percent more saw timber per ha. Michaelis points out that if the 4 million ha of timberland in that region were managed intensively, the area could produce an increment equivalent to "10% of US sawnwood production.

Binkley (1997) estimates that if intensive techniques were applied on a zoned basis in British Columbia, yields could on average be increased from the current average of 2.2 m^3/ha/yr to a target level of 5.9, or roughly by a factor of two to three. He estimates that this concept could increase the long-term sustainable harvest from 70 million m^3 to 100 million m^3 annually in the long-term and at the same time, make available some 70 million ha for uses other than timber production. The paper does not discuss the economic aspects of the concept, which raises the question of the impact of the effect of time on the discounted value of the eventual harvest, given what presumably would be rotation ages of at least 50 to 60 years and the need for expenditures to be made in the early stages of the cycle. Also not addressed is the impact upon the timing of harvest flows from the intensively managed forest areas and the extent to which these volumes would differ materially over, say, a fifty year period from those projected for current forest management practices.

6.6 Expansion potential of 'non-traditional' supply sources

The need for plantations: a consensus. An earlier section of this report noted that a review of the literature on global forestry indicated a general agreement with respect to the need for forest plantations to provide a key component of future IRW supply. The following quotations from recent papers perhaps best express what appears to be a strong consensus:

- "We simply cannot meet our demands for solidwood, wood pulp, fuelwood and other forest values from naturally-growing native forests alone. We're dependent on planted forests"(Boyle 1999).

- "Planted forests are the world's best hope for meeting global wood requirements in the 21st century" (Powers 1999).

- It is inevitable that global tree farms will take an ever increasing role in wood supply. The traditional dominance of the world's native forests in providing global wood fiber needs can not continue" (Neilson 1999).

Although there is a general (but not full) agreement as to the need for plantations, there has been relatively little attention given to where new plantations will be developed , at what rate, and of what type.

Plantations in the1990s. Reliable, definitive information regarding existing plantations is notoriously weak. Definitions are blurred and confused and the data often inaccurate and/or incomplete. FAO has undertaken the task of developing a comprehensive database and has made good progress with work still in process. Whiteman and Brown (1999) of FAO estimate that of the 120 million ha of global forest plantation area, between 70 and 100 million ha will be used for IRW supply. Of this, about half is located in China, India and Japan. The United States and Russia account for about 15 million ha each. The balance is distributed in a further 13 countries each with more than 1 million ha.

The area of short-rotation, high-yield (>14 m^3/ha/yr) plantations is not given, however it is relatively small, probably less than 15 million m^3 and located primarily in Latin America, Oceania, and Indonesia. Nevertheless, this sub-sector has the greatest potential for significant additions to IRW supply.

The plantation development incentive. The motivations for IRW plantations are varied. For governments, depending upon growing conditions, land-availability and the extent and nature of natural forest resources, plantations can provide the potential for import substitution, industrial and export development, and the possibility of reclaiming degraded land.

Plantations offer the private sector the potential to select the resource location, pre-determine and/or modify fiber characteristics, and most importantly, develop a secure source of low-cost roundwood. Low wood costs, long-term supply security, and access to markets are arguably the key determinants of competitive

position for a forest products firm. Those countries and/or regions that can provide such potential in the context of reasonable "country risk" should enjoy a clear comparative advantage.

As Gadgil and Bain (1999) have observed, "It is economics that largely drives plantation forestry. Most plantation forests are established and managed for profit." That said, it is biology that drives the economics. As Kanowski (1992) notes "the principal attraction of plantation forests is their productivity relative to most forest systems."

The relative productivity of plantations relative to natural forest yields is demonstrated in Table 3.

Table 3. Typical timber yields

	Yield (m^3/ha/yr	Rotation (yr)
Temperate & boreal conifer forests		
British Columbia	**1.5-5.3**	
Sweden	**3.3**	
Finland	**2.5**	**60-100**
Siberia	**1.0-1.4**	**70-200**
Plantations - conifers		
Britain	**14**	**40**
New Zealand	**18-30**	**20-40**
Brazil	**15-35**	**15-35**
Chile	**20-30**	**15-35**
Plantations – non-conifers		
Brazil	**30-45+**	**7-20**
Chile	**20-30**	**8-20**
Portugal & Spain	**10-15**	**8-15**

Source: Adapted from Sedjo (1999)

The impact of the plantation yields is great. At an estimated yield of 15 m^3/ha/yr, an area of about 3% of the world's total closed forest could *in theory* provide the current IRW requirement. While this is admittedly grossly simplistic, it does underscore the potential offered by high yield plantations.

Government involvement. Most high-yield plantations were initially developed with some form of government subsidy. This has been the case, for example, in Brazil, Chile and New Zealand, three of the world's leading high-yield plantation countries. Today, however, most countries have removed direct subsidies for plantation establishment. While this has slowed the planting rate in some cases, (most notably Brazil) it has not stopped further establishment investments by the private sector. The state has also been involved in promoting the afforestation of land taken out of agricultural production, principally in countries of the EU, the USA and some Eastern European countries (Pandey and Ball 1998).

Issues. There is a variety of issues with respect to the social and environmental aspects of plantations, and particulary high-yield plantations. While these are complex, none should preclude plantation development, providing that such development is carried out with due concern to the sensitivities and established "best practices". The economic case against high-yield plantations is made by Oliver (1999), who holds that the high establishment costs of plantations require high yields and short rotations – which in turn add further to establishment costs. In his view, the emphasis on short rotations will lead to a surplus of small diameter and low quality wood.

Successful implementation. If future IRW requirements are to be met, it is vitally important not only that sufficient areas of plantations are established, but that the development is done in such a way that the plantations will be economically, technically and socially sustainable over the long-term. This has not always been the case; there have been failures. Evans (1999) identifies the leading causes of failures in tropical plantations as: land tenure problems, lack of participation by local people, and inadequate attention to proper planning, budgeting and market evaluation. In his view, failure to address these matters will override species choice, silviculture and management.

Conversely, Nielson (1997) cites the following criteria for successful plantation development:

- country economic and political conditions conducive to investment
- sufficient land to build up a resource without unduly impacting land prices or leases
- low population in the plantation area
- a fast growing tree species
- a proven species technology
- market access

Outlook. At the outset of this section, it was noted that based on the assumed growth in the demand for IRW, there would be an increasing annual increment reaching in the order of one billion m^3 by 2050. From the literature, it is clear that the natural forests of the world, given the various constraints faced, will be unable to supply this increment. While technological developments are expected to continue to improve the unit utilization rate of IRW, they cannot reasonably be expected to alleviate the need for significant increases in IRW over the 50-year period. While intensive management of natural forest resources can improve yields over the long-term, the further development of intensively managed plantations appears to provide the most significant potential for additional supply to 2050.

Whiteman and Brown (FAO 1999), utilizing the FAO global fiber supply model, have prepared a preliminary forest plantation analysis. This work includes a plantation age-class distribution which indicates that 50% of the plantation area has been planted in the past 15 years and nearly 25% in the past 5 years. This implies a dramatic increase in the flow of IRW from plantations during the next 10 years, although there is no indication as to the distribution between sawlogs and pulplogs. After about 2010 however, the plantation supply profile will depend very much on the rate of planting from 2000 onward.

The FAO team has put forward three preliminary scenarios to the year 2050 in which the rate of planting is varied. The most probable range lies between the assumption of a constant rate of 1.2 million ha/yr throughout the period, and alternatively, a continuation of the apparent 1995 planting rate taken out to 2010 and then reduced progressively over the remaining 40-year period. The range of IRW volumes under these assumptions lies between 850 million m^3 and 1.4 billion m^3 in 2050. The authors caution that there is " a considerable amount of uncertainty" associated with the projection due to the effect of declining income elasticity of demand for wood products with rising income levels. In any event, the analysis provides at least a very preliminary notion of the orders of magnitude involved, and of the level of planting required.

Plantation establishment rates reflect a complex mix of variables, which tend to defy prediction. Given that the bulk of the high-yield component is likely to be planted by private capital, the question arises as to the extent to which capital will be invested in the face of an apparent increase in the volume of plantation wood forthcoming in the short term. Experience from other sectors of the forest industry tends to suggest that capital investments are made when the supply/demand balance is 'tight' – and not when there is a surplus

of supply with accompanying low prices. Should this be the case future plantation age-distributions will be irregular, putting stress on short-term wood supply in many regions.

The location of future plantation developments and the availability of suitable land are topics that are seldom addressed in the literature. According to Evans (1999), there is plenty of degraded land resulting from past clearance or poor farming practices and which is of no importance for conservation but will grow trees well. In support of this position, a CINTRAFOR (1998) working paper on Argentina states that the government estimates that *20 million ha* of land suitable to forestry is available in addition to the 1 million ha already planted.

Given that the most attractive regions for developing high-yield plantations in biological terms are mainly in the southern hemisphere, it is reasonable to assume that future plantings of high-yield plantations will follow the already established pattern of developments in South America, Oceania and southeast Asia. The actual distribution will be a function of the variables determining success as previously outlined.

Simply simply applying an arbitrary cost/ha of, say, $1,500/ha gives a very crude estimate of the plantation establishment costs inherent in the FAO scenarios. The resultant range of annual costs is in the order of $2 billion throughout the 50-year period and alternatively, $7 billion/yr for the next 10 years then tapering off to zero by 2050.

Assessment

Global forestry is in transition. As with earlier transitions, it is accompanied by some turbulence. However, the positive aspect is that there is a huge body of experience and science to draw upon and the goal of achieving what Michaelis (1993) refers to as "a globally optimal solution" which meets the needs of all should certainly be attainable.

Given the 50-year time span under consideration, perhaps all that one can realistically hope to achieve is some sense of direction, given the trends and dynamics as we now understand them. In this context, Mather (1993) is helpful. Based on his research he states that "…it is difficult to avoid the conclusion that the scope for opening up of major new regions of supply from natural old-growth forests is limited. The switch from natural to planted forests will not happen over night, but the trend seems inexorable…". He concludes that new patterns of supply are not only possible but also likely, given the ability for plantations to be developed in those sites that optimize the key success criteria. These patterns are likely to be more dispersed and more global than the ones they replace.

It seems clear based current evidence that by the year 2050 global IRW supply will be far more heavily dependent on plantations than is presently the case. A share in the order of 50% does not seem untoward given the projections already made by Hagler, Jaakko Poyry, FAO and others. For this to happen, continuing and accelerated establishment rates will be required in the short term to medium term.

It is essential, however, that plantation development be achieved in a rational and balanced way, particulary with respect to appropriate age distributions and a mix of log types matched to end-use requirements. Assuming the existence of open economies, an absence of trade barriers, and transparent stumpage prices that reflect timber's true competitive value, the market, represented by many domestic and international players, will respond to actual or anticipated higher demand and tightening supply. As Binkley (1989) puts it, "timber prices signal the relative scarcity of wood and thereby coordinate virtually all of the key facts of forest-sector development."

The resultant decision-making process could be greatly facilitated and enhanced by the availability of an integrated, comprehensive, detailed and accurate information base with respect to all aspects of the global plantation estate. This would be particulary helpful in assisting planners and investors to fully appreciate the time factor which is inherent in all forestry operations, but which is particulary critical in intensive management with its high "up-front" costs and sensitivity to the time-value of capital investments. As Michaelis has observed, industry participants occasionally look at short time intervals and are lulled into a false sense of security. As the world – and forestry –becomes increasingly 'global' it is vitally important that all those involved be able to form a reasoned 'long view' based on sound information.

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