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The potential role of forest plantations in meeting future demands for industrial wood products[1]

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SUMMARY

This paper presents a forecast of the supply and demand for wood and wood products to the year 2010 and three forecasts of future potential industrial roundwood supply from forest plantations to the year 2050. The forecasts predict that overall wood supply and demand is expected to increase by about 25% from 1996 levels to just under 1.9 billion m^3 in 2010. Of this, it is expected that the potential supply from forest plantations will increase from around one-quarter of total supply at present, to around one-third of total supply in 2010. Beyond this year, the importance of forest plantations to total wood supply is expected to continue to increase, but this will depend upon current and future rates of new planting. Other expected changes in future supply include the increased use of residues, recycled fibres and trees outside of forests; and an increased scarcity of high value roundwood. Changes to the harvesting regimes used in natural forests and the introduction of new technology are the two factors most likely to affect these forecasts. Governments have some influence over future supply patterns and it is suggested that roundwood pricing (where this is set by the government), support to plantation establishment and human resource development are three priority areas that should be examined.

Keywords: supply and demand forecasts, forest plantations, forestry policy

INTRODUCTION

Forecasts of the future supply and demand for wood and wood products are an important aid to planning and decision making in the forestry sector. Consequently, the Food and Agriculture Organization of the United Nations (FAO) carries-out periodic reviews of global forest product markets in order to produce supply and demand forecasts. The forecasts presented here come from the latest of FAO's global forest products market studies, which have been produced approximately every five years since 1982. The current study has attempted to go beyond just simply producing forecasts however, to examine and describe a number of factors that might influence future supply and demand and to discuss the implications of these forecasts for forest management and policy development. This has included an analysis of the potential for forest plantations to meet future wood demands (Brown, in prep), a summary of which is presented here.

The rest of this paper is in five sections. The first section describes the supply and demand models used by FAO to produce forecasts and the second section presents a summary of the forecasts to the year 2010. The third section explains the model used to estimate the future potential supply of

[1] This research was carried out as part of the FAO Forestry Department programme of work on outlook studies. The views expressed here are those of the authors and do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

industrial roundwood from forest plantations. The fourth section discusses some of the trends in forest plantation establishment that have been observed in the analysis and presents three forecasts of future supply potential, based on different scenarios for future forest plantation development. The final section indicates the contribution that forest plantations might make towards meeting future demands for industrial wood products and discusses some of the implications of the supply and demand forecasts for forest management and policy development.

THE 1999 GLOBAL FOREST PRODUCTS OUTLOOK STUDY

For over three decades now, timber market analysts have been producing wood supply and demand forecasts at the national, regional and global level. FAO has already produced several global supply and demand studies (FAO, 1982; FAO 1986; FAO 1988; and FAO, 1997a) and has supported several studies at the regional level in Europe (UN, 1996 and earlier), North America (Boulter and Darr, 1996) and the Asia-Pacific region (FAO, 1998). A number of other analysts have also produced global supply and demand studies (for a comprehensive review of most of these studies, see: Solberg *et al*, 1996). These studies have all generally followed similar approaches to the modelling of supply and demand.

On the demand side, most of these studies have been based on econometric analysis of past trends in demand. Such an analysis examines how historical changes in demand can be explained by changes in price and changes in other underlying variables that shift the demand curve. There are likely to be a number of variables that shift the demand for wood and wood products, including changes in incomes, tastes and technology. However, it is often very difficult to identify the effects of each of these variables separately, because they tend to be highly correlated. Therefore, broad "demand shifters" (such as national income) have typically been used in these studies, on the assumption that they capture the combined effect of many of these highly correlated variables.

After estimating the magnitude of these effects on demand (i.e. their *elasticities*), future projections of these variables (e.g. price and national income) are then used with the econometric model to produce forecasts of future demand. This approach can generally only be used to produce forecasts of the demand for finished products (e.g. sawnwood, paper and panel products), but demand forecasts for intermediate products and raw materials (such as roundwood and pulp) can be derived from these using conversion factors. These factors may change in the future (e.g. due to changes in processing technology) and this is also sometimes built into the demand forecasts.

In a similar way, most forecasts of future supply are based on an analysis of information about past changes in supply, price and other variables. In the case of finished products, these other variables usually include: roundwood supply and cost; manufacturing cost; capacity and other technical parameters. However, in the case of roundwood supply, such models are often primarily based on biological variables, such as: the volume of standing growing stock (or forest inventory); the annual allowable cut (AAC); or the volume of timber reaching economic maturity. Future projections of these variables are then used, along with the supply model, to produce supply forecasts.

Generally, the most challenging part of these studies is the modelling of roundwood supply. This is sometimes difficult because of incomplete or inaccurate information about forest areas, growth and

yield. However, a more general problem is the difficulty of identifying and estimating the impact of non-biological variables on supply, such as: harvesting costs; product prices; non-financial forest management objectives; and forestry policies. A further challenge when attempting to model supply and demand at the global level is that, by definition, total supply must equal total demand and the projected supply of raw materials and intermediate products must be sufficient to meet the projected supply of finished products. In its most recent global forest products market study, FAO has attempted to address some of these challenges with its two main supply and demand models and these are briefly described below.

The Global Fibre Supply Model (GFSM)

The GFSM is a model of future potential wood and fibre supply that covers the 78 largest wood producing countries outside Europe and North America. Forecasts for countries in Europe and North America are not produced by the model, because they have already been produced in the fifth European Timber Trends Study (UN, 1996) and the North American Timber Trends Study (Boulter and Darr, 1996). However, it should be noted that the forecasts contained in these studies are not entirely comparable to those produced by the GFSM, in that they are forecasts of expected actual supply rather than supply potential.

The GFSM is based on a comprehensive database that contains information about forest resources and recovered and non-wood fibre supply. Examples of the information contained in the database include: forest area and stocking; forest growth rates or potential yields; harvesting intensity; harvesting efficiency; levels of wastepaper recovery; and non-wood fibre pulping capacity. For most countries, the information about forest resources is disaggregated into broadly defined forest types. The area of each forest type is also split into areas that have been logged and unlogged areas and areas that are potentially available for wood supply or are unavailable for a number of reasons (e.g. due to legal restrictions, biological factors, or reasons of economic or physical inaccessibility). For forest plantations, the model currently includes relatively simple information about area, species and potential growth rates or yield.

The model calculates future potential wood supply as a function of forest area multiplied by harvesting intensity (in the case of unlogged forest) or yield (in forest plantations and logged forest),[2] for each of the forest types available for wood supply in each country. In the absence of more detailed data, the model also applies reduction factors to the potential supply from forest plantations, to take into account the current age-structure of forest plantations in each country. The supply forecasts for all types of forest are also reduced to take into account harvesting efficiency. In addition to these forest-based supply components, estimates of future potential wastepaper recovery and non-wood fibre utilisation are also incorporated into the final estimate of total potential wood and fibre supply.

The model can be used to produce potential supply forecasts under a range of alternative assumptions about rates of deforestation, levels of harvesting intensity in unlogged forest, forest growth or yield in logged forest and forest plantations and the expansion of the harvesting frontier

[2] For example, it may be possible to harvest at an intensity of 50 m^3/ha in a forest on the first cut, but then only 30 m^3/ha when the forest is cut for a second time (due to the rate of regrowth and the felling cycle).

into previously inaccessible forest. Changes in future rates of forest plantation establishment, wastepaper recovery and non-wood pulping capacity are also important variables that can affect future potential supply and scenarios for these variables can be examined in the model (for further information about the data and models used in the GFSM, see: Bull *et al*, 1998). The scenario used in the analysis presented here is one of a continuation of past trends in most of these variables.

The Global Forest Products Model (GFPM)

The GFPM produces forecasts of wood and wood product production, consumption and trade, that cover 14 product categories in each of the 180 largest countries in the world. The model is a market simulation model and is based on a linear programming algorithm. This simulates trade between countries, subject to the constraint that total world exports of each product must equal total world imports. Other constraints within the model ensure that the forecasts it produces are internally consistent (e.g. they ensure that forecast industrial roundwood supply is sufficient to meet the forecast level of finished product supply in each country, after allowing for trade in industrial roundwood).

The whole GFPM modelling process is quite complex (see Tomberlin *et al* (1998) for a more detailed discussion), but it can be simply explained as follows. The first stage of the process is to analyse historical data to estimate supply and demand elasticities for all countries in the model. Price elasticities are used to define the slope of the supply and demand curves that will be used in the model. Other elasticities (that measure the effect of variables that shift the supply and demand curves) are used to move the curves between adjacent years of the forecast.

The model only requires demand elasticities for final products and supply elasticities for roundwood and other fibre supply. Supply and demand curves for other components of the model (e.g. the supply of finished products and the derived demand for intermediate products and raw materials[3]) are constructed from these within the model, using a series of technical coefficients.

The GFPM then creates a set of supply and demand curves for each product in each country in the base-year (the base-year is the last year for which actual data exists). These are first located so that they match the actual production, consumption and trade figures recorded for the base-year. As part of this process, the model is calibrated (i.e. some of the internal parameters are adjusted) until it produces an internally consistent forecast for all products in the base-year that is reasonably close to what was actually recorded.

The model then shifts all the demand and supply curves, according to the set of predetermined elasticities, in order to produce a new set of supply and demand curves for the next year of the forecast. At first, this produces a set of results that differ greatly, in terms of price, between countries (i.e. countries with high demand growth but low supply growth show very high prices and countries with low demand growth but high supply growth show low prices). However, the model then moves the supply curves around to simulate trade (i.e. countries with low prices export to countries with

[3] It should be noted that, in contrast to the GFSM, the GFPM produces forecasts of actual roundwood demand and, hence, actual roundwood supply, rather than potential supply.

high prices) until prices start to converge.[4] It should be noted that this process is *price-endogenous*, in other words price forecasts are produced as an output of the model (as a result of these shifts in supply and demand) and are not entered into the model as explanatory variables.

This process is subject to the constraints that the net supply in each country (i.e. accounting for the effects of trade) must equal domestic demand and that total world exports and imports must balance. It must also meet certain other constraints, such as the requirement for internal consistency noted above. This process of shifting the supply and demand curves and simulating trade in each year is then repeated for every year of the forecast period.

The price and income demand elasticities used in the GFPM were based on an econometric analysis of production data taken from the Forest Products Yearbook (FAO, 1996 and earlier) and economic data taken from the World Bank STARS database (World Bank, 1993). On the supply side, estimates of the price elasticity of industrial roundwood supply were taken from the forest economics research literature. With respect to the roundwood supply-shifter, it was assumed that the roundwood supply curve in each country would shift in response to changes in expected actual supply (in the case of Europe and North America) or supply potential (in the case of all other countries), with an elasticity of 1.0. There is some evidence to support this assumption, for example Hyde and Newman (1991), in a comprehensive review of roundwood supply models, found that many analyses of timber supply have identified a supply elasticity of 1.0 or close to 1.0, with respect to biological measures of supply potential.

The economic growth projections used to shift the demand curves between years were taken from existing FAO research in this area (FAO, 1997b). Projected shifts in the roundwood supply curves were taken from the results of the GFSM and the European and North American Timber Trends Studies.

The links between finished product demand, finished product supply and raw material demand in the model, are specified as a series of technical functions and coefficients, such as: roundwood to product conversion factors; estimates of manufacturing costs; capacity utilisation parameters; and wastepaper recovery rates. This information is used within the model to derive the demand curves for raw materials and intermediate products and the supply curves for intermediate and finished products. It is also used to derive some of the constraints used in the model.

The conversion factors used in the model were calculated from production and consumption figures contained in the Forest Products Yearbook. For example, if a country reports a level of sawlog inputs to its processing industry equal to twice the level of sawnwood output (and no plywood production), then a conversion factor of 2.0 would be derived. Estimates of manufacturing cost were also derived from these data by subtracting raw material input costs (e.g. roundwood prices multiplied by the conversion factor for a particular product) from product prices. International trade prices were used throughout the analysis, by dividing the trade values reported in the Forest Products Yearbook, by reported trade volumes.

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[4] Technically, this solution is achieved by changing the quantity estimates in each country until the total sum of consumer and producer surplus in the world is maximised.

The baseline analysis presented here assumes no change in future technology, except that it assumes that the recovery and utilisation of wastepaper will increase in the future at the same rate as it has in the past. While this may not be achievable indefinitely, this will be feasible in the period to 2010 and is likely to occur given the current emphasis on increasing recycling in many countries.

FORECASTS OF FUTURE SUPPLY AND DEMAND TO 2010

The main results of the 1999 Global Forest Products Outlook Study are shown in the two tables below. Table 1 shows the forecasts, to the year 2010, of overall supply and demand by broad geographical region and Table 2 shows the global supply and demand forecasts by main product categories. More detailed forecasts by individual country and product categories can be found in Zhu *et al* (1998).

The forecasts presented here only extend to the year 2010, because of the uncertainty surrounding the projections of the explanatory variables used in the model. The impact of any errors in these projections would be magnified over a longer forecast period. For example, over 50 years, an error of 0.5% in the annual growth rate of national income would result in an absolute difference in national income of some 30% by the end of the period and a very different forecast of future supply and demand.

Supply and demand by geographical region

Table 1 shows that global industrial forest product production and consumption is projected to increase at an annual rate of about 1.7%. However, the expected level of consumption in 2010 (1.9 billion m^3 EQ) will only be about 10% higher than the peak in consumption (of 1.7 billion m^3 EQ) experienced around 1990.

The table also highlights the differences in supply and demand growth expected between the different regions. The highest rates of growth in supply and demand are expected in Asia and Oceania, despite the recent economic problems experienced in Asia (see FAO (1998) for a further discussion of this issue). In contrast, relatively slow growth in supply and demand is expected in North and Central America and only moderate increases are expected in Africa and South America. However, North and Central America will remain the largest producing and exporting region, although in terms of its share of global consumption it will continue to fall behind Asia.

TABLE 1 *Industrial roundwood production, finished wood product production and finished wood product consumption in 1996 and forecast for 2010*

Region	Industrial roundwood production (million m^3)			Product production (million m^3 EQ)			Product consumption (million m^3 EQ)		
	1996	2010	Annual growth	1996	2010	Annual growth	1996	2010	Annual growth
Africa	68	84	1.5%	61	74	1.4%	35	37	0.6%
Asia	280	421	3.0%	334	479	2.6%	510	653	2.1%
Oceania	41	54	1.9%	23	39	3.8%	18	28	3.3%
Europe	370	502	2.2%	368	509	2.4%	347	469	2.4%
N & C America	600	658	0.7%	585	639	0.7%	499	589	0.8%
S America	130	153	1.2%	120	131	0.7%	80	97	1.4%
WORLD	1,490	1,872	1.7%	1,490	1,872	1.7%	1,490	1,872	1.7%

Note: Finished wood product production and consumption have been converted to their roundwood equivalents (m^3 EQ) to be comparable to the industrial roundwood production figures.

In terms of trade, Asia will continue to produce more finished wood products than industrial roundwood and, therefore, continue to be a net industrial roundwood importer. Asia will also continue to be the world's only net importing region of finished wood products. Three countries in Asia (Japan, China and Republic of Korea) account for the majority of this net import demand.

Overall, major changes in trading patterns are not expected in the future, but the shape and form of trade will continue to change. Firstly, many countries are expected to continue giving priority to developing manufacturing capacity to process, rather than export, raw materials and intermediate products such as roundwood and pulp. Similarly, greater trade in higher value-added products is also expected in the future. Secondly, as developing countries continue to grow and mature, their domestic markets are expected to expand and some of this expansion will be at the expense of their export markets.

Supply and demand by product category

Table 2 shows that the supply and demand for paper and paperboard is expected to grow faster than other products in the period to 2010, increasing at an annual rate of 2.4% per year. In contrast, the use of pulp is only expected to rise by 1.1% per year, reflecting the expected increase in the use of recovered paper in the total fibre furnish. Supply and demand for solid wood products is expected to grow moderately: 1.1% per annum in the case of sawnwood and 1.3% per annum for wood-based panels. The highest growth in wood-based panel supply and demand is expected in reconstituted wood panels rather than the plywood sector.

TABLE 2 *Forecast future supply and demand by product category for 1996 and 2010*

Product category	Production/consumption		Total growth	Annual growth
	1996	2010	1996-2010	1996-2010
Industrial roundwood	1,490	1,872	26%	1.6%
Sawnwood	430	501	17%	1.1%
Wood-based panels	149	180	20%	1.3%
Pulp	179	208	16%	1.1%
Paper and paperboard	284	394	39%	2.4%

Note: Volume figures for roundwood, sawnwood and wood-based panels are in million m^3, figures for pulp and paper are in million metric tonnes.

Future roundwood and fibre supply compared with supply potential

The projected expansion of wood product supply and demand will undoubtedly require an increase in roundwood and fibre supply. This is of interest because it will affect the way in which forests might be managed in the future and this information provides a useful input to forestry policy analysis.

The first point worth noting, is that the ability of the forestry sector to respond to these changes will differ widely between countries. In some countries, wood supplies may be expanded by opening up new areas of forest or by taking advantage of maturing forest plantations. In other countries, the forest industry will respond by trying to achieve greater efficiency in harvesting and processing, or by starting to utilise a much broader and more diverse range of wood and fibre supplies. For example, a detailed analysis of supply and demand in the Asia-Pacific region (FAO, 1998) showed that many countries there are already starting to use a more diverse range of forest and non-forest supply sources in order to meet their production needs, in response to greater scarcity of certain types of raw material.

FAO does not yet have sufficient data to make a robust and accurate assessment of global wood and fibre supply potential. For example, the GFSM covers a large part of the world, but doesn't cover the important contribution (to wood supply) of trees outside of forests. However, the GFSM can be used to compare projected levels of supply with supply potential from forests and recovered and non-wood fibre sources across some regions. Such a comparison has shown that forecast supply levels are well within the expected limits of supply potential in South America and Oceania, but approaching the limits in Asia and Africa (FAO, 1999). This comparison has also shown that supplies of large logs are becoming increasingly scarce in Asia and Africa. Therefore, consumers of wood and fibre in these areas will look increasingly to alternative supply sources to meet this demand. It is also likely that the markets for forest products will continue to respond to this scarcity, by moving towards replacing sawnwood and plywood with other wood-based panels and engineered wood products, which can be manufactured from small-sized wood or roundwood substitutes.

THE FOREST PLANTATIONS OUTLOOK STUDY

Almost all of the recent studies of global supply and demand agree that forest plantations will play an increasing role in meeting future demands for industrial roundwood. However, most efforts to

quantify the current and future potential contribution of forest plantations to global roundwood supply have suffered from a lack of detailed information about forest plantations in many countries. In particular, there are two common problems with the forest plantation statistics currently reported for many countries. Firstly, in many countries it is often difficult to define exactly what is a forest plantation and, even where precise definitions are available, they are often not comparable across countries. Secondly, the area statistics reported for some countries are misleading for a number of reasons (e.g. they don't include areas planted by the private sector; they include areas where establishment fails shortly after planting; or they don't distinguish between new planting and replanting).

FAO has set-out to improve upon this situation by extending the work, already started by Pandey (1995 and in prep) and in the GFSM, as part of the Global Forest Products Outlook Study. This has included the development of a more comprehensive and reliable database of forest plantations and the construction of a potential supply model. This new database contains better information about areas, species, utilisation (i.e. for industrial roundwood supply or for other uses), potential yields and typical management regimes and the model can be used to produce more detailed estimates of the current and future potential supply of roundwood from forest plantations.

The estimation of age-class profiles in the forest plantation supply model

A major component of the forest plantations outlook study has been the estimation of age-class profiles to add to existing information about forest plantation areas and species distributions. This information has been estimated for the 65 countries with more than 100,000 ha of forest plantations, which are believed to contain the vast majority of the world's forest plantation resources.

The estimated age-class profiles have been based on information collected from a variety of sources, including: official national and international statistics; bibliographic references; project reports and expert opinion. However, for many countries, only partial forest plantation data is readily available and it has been necessary to use a variety of techniques to fill-in missing data. While these manipulations have undoubtedly produced age-class profiles of varying quality, they have made it possible construct profiles that are broadly representative of the forest plantations in each country and consistent with their reported statistics.

Modelling the potential supply of wood from forest plantations

Given the quality of information available about many of the factors that influence wood supply from forest plantations, a relatively straightforward supply forecasting methodology has been chosen for this analysis. The main pieces of information used in the model are: forest plantation area (disaggregated by species); the national forest plantation age-class profiles (grouped by 5-year intervals); and national estimates of increment (by species). Other information used in the model includes information about typical rotation ages (by species) and indicative national mortality rates.

The model works on an annual basis. Each year, the areas of each species that are harvested and lost due to natural causes (in each age-class) are estimated from the information about rotation ages and mortality. These areas are assumed to be replanted immediately and, along with any new planting, are placed into the 0-5 years age-class. At the same time, a proportion of the remaining

forest plantation area in each age-class is moved into a higher age-class. In order to estimate potential wood supply, the area of each species harvested in each age-class, is then multiplied by the mean annual increment for that species and the age at harvest (this calculation assumes that there is no thinning of forest plantations). These estimates are then summed to give total potential roundwood supply for this year and the process is started again for the next year of the forecast.

RESULTS OF THE FOREST PLANTATION ANALYSIS

The most recent estimate of the global forest plantation area is just under 120 million ha. Almost half of this area is located in Asia (see Table 3), where the majority of forest plantations can be found in China, India and Japan. These three countries, along with the Russian Federation and the United States of America, each have more than 10 million ha of forest plantations and a further 13 countries each have more than 1 million ha.

Information about the likely utilisation of these forest plantations suggests that the majority (between 70 million ha and 100 million ha) will be used to supply industrial roundwood. The remaining areas have been planted for a variety of non-industrial uses, including: fuelwood production; site reclamation; production of non-wood forest products; and watershed protection. Undoubtedly, most of these areas will also eventually be cut, but it has been assumed in this analysis that they will be used to supply fuelwood, rather than industrial roundwood.

TABLE 3 *Estimated global distribution of forest plantation resources in 1995*

Region/country	Forest plantation utilisation and area (in million ha)		
	For industrial roundwood supply	For non-industrial uses	Total
Africa	3.6	2.1	5.7
Asia	41.8	15.1	56.9
China	*17.5*	*3.9*	*21.4*
India	*4.1*	*8.3*	*12.4*
Japan	*10.7*	*0.0*	*10.7*
Oceania	2.7	<0.1	2.7
Europe	n.a.	n.a.	30.9
Russian Federation	*n.a.*	*n.a.*	*17.1*
North and Central America	14.2	0.3	14.5
United States of America	*13.7*	*0.0*	*13.7*
South America	6.1	2.1	8.2
WORLD	n.a.	n.a.	118.9

Source: FAO and UNECE

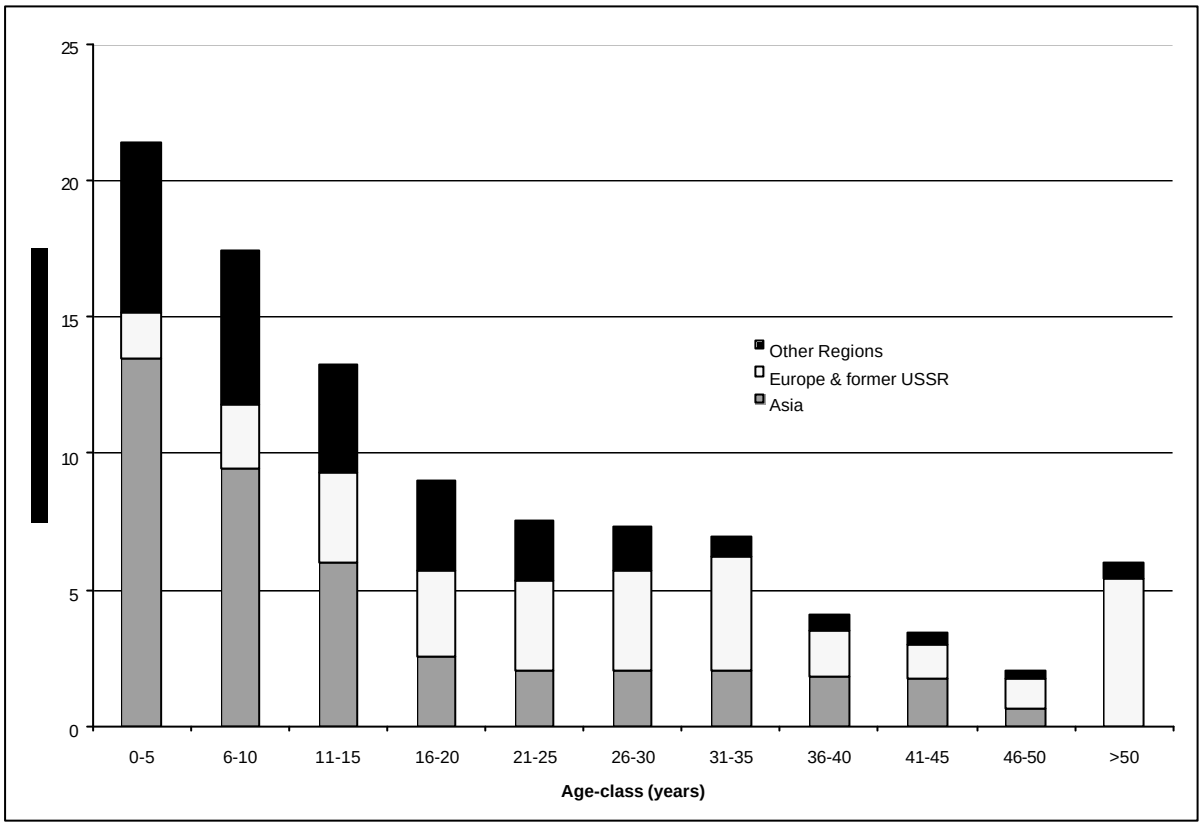

FIGURE 1 *The estimated global forest plantation age-class structure (in 1995)*

The construction of the national forest plantation age-class profiles has highlighted some significant trends in new planting during the past 20 years. The most notable of these is the acceleration in new planting rates that has occurred since 1970, predominantly in Asia, South America and Oceania. This has gradually shifted the largest share of the global forest plantation resource towards Asia and away from Europe. For example, around 90% of the forest plantations established more than 50 years ago were planted in Europe, but over 60% of the forest plantations established in the past 5 years can be found in Asia (see Figure 1). Other trends worth noting are that over 50% of the forest plantation area has been planted in the past 15 years and nearly 25% has been planted in the past 5 years. The most important implication of this is that the potential supply of wood from forest plantations is likely to increase dramatically during the next two decades from the areas that have already been planted.

Based on this information, the forest plantation supply model suggests that the current level of potential industrial roundwood supply from forest plantations is around 370 million m^3 per year, which is equal to about 25% of global industrial roundwood production. It should also be noted however, that this varies considerably between geographical regions, with forest plantations having the potential to supply nearly 80% of the industrial roundwood currently produced in Oceania, but only 15% of current production in North and Central America.

Estimates of future potential supply from forest plantations

The future potential supply of industrial roundwood from forest plantations will depend upon a number of factors. The most crucial factor will be the rate at which new planting is sustained, although improvements in fields such as plant breeding, silvicultural techniques, plant survival and harvesting techniques, are all likely to contribute to greater productivity. This analysis has assumed that the latter variables will all remain unchanged and has concentrated on producing three future scenarios for new planting, in order to forecast potential industrial roundwood supply from forest plantations through to the year 2050.

Scenario 1 provides a baseline forecast, by assuming that forest plantations are not expanded beyond their current area and that all areas are replanted after harvesting.

Scenario 2 assumes that new planting will increase the forest plantation area at a constant rate of 1.2 million ha per annum in total (equal to 1% of the current area of forest plantations).

Scenario 3 assumes that the annual rate of new planting estimated in 1995 (4.71 million ha in total) is maintained until the year 2010, after which it is reduced by 940,000 ha at the start of each of the following decades (i.e. until it declines to zero in 2050).

All three of these scenarios assume that the geographical distribution of the global forest plantation estate will not change (in other words, that any new planting will take place in proportion to the current share of forest plantations located in each country). However, the age-class structure (and hence the annual volume harvested) in each country will change over time, in response to harvesting, replanting and new planting.

The forecasts of potential industrial roundwood supply from forest plantations, under each of these scenarios, are shown in Figure 2. By the year 2010, there is very little difference between the three scenarios, with scenarios 1 and 2 showing a potential supply of 560 million m^3 (or 51% more than the supply potential in 1995) and scenario 3 showing a slightly greater increase to 620 million m^3 (or +68% on the 1995 level). However, in the long run, there are considerable differences between the three scenarios. The forecast for potential industrial roundwood supply from forest plantations under scenarios 1 and 2, both reach a maximum in 2045. The maximum is 690 million m^3 (or 86% greater than in 1995) under scenario 1 or 850 million m^3 (+130%) under scenario 2. Under scenario 3, the forecast continues to increase to 1,430 million m^3 in 2050, a level that is 286% higher than the estimated potential for 1995.

The forecast for total industrial roundwood supply and demand (produced by the GFSM) only extends to 2010. However, many of the more interesting aspects of the plantation supply forecasts appear after this year. Therefore, in order to put the forest plantation forecast into context, an extrapolation of total industrial roundwood supply and demand for the years 2030 and 2050 has also been produced and is shown in Table 4. This extension to the GFSM forecast has been very simply produced by applying the average annual rate of growth, from the forecast for 1996 to 2010, to the period 2010 to 2050. It must be stressed that there is a considerable amount of uncertainty associated with this extension. In particular, the extrapolation is likely to overestimate future supply and demand, because the income elasticity of demand for wood products tends to decline as incomes rise.

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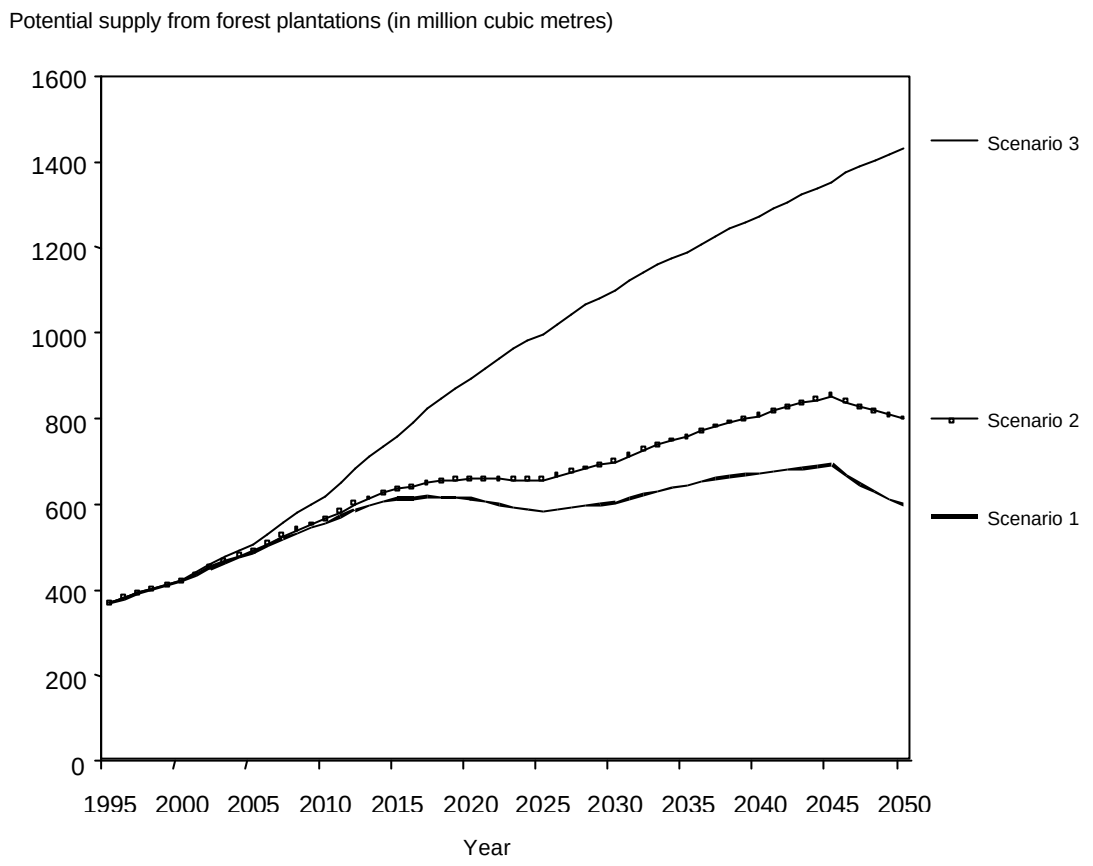
FIGURE 2 *Potential industrial roundwood supply from forest plantations 1995 -2050*



As Table 4 shows, the proportion of future industrial roundwood supply that might be produced by forest plantations will increase to between 30% and 33% by the year 2010, depending on how much new planting occurs. After this, the divergence between the three scenarios produces in very different results. With no new planting (scenario 1), the importance of forest plantations as a source of industrial roundwood supply might decline somewhat whereas, under scenario 2, their importance may remain about the same as in 1995. Scenario 3 shows that, with a higher rate of new planting, the future potential supply from forest plantations could reach a much greater proportion of the world's total industrial roundwood supply by 2050.

TABLE 4 *The proportion of industrial roundwood supply that might come from forest plantations in the future*

Volumes in million m^3

Supply scenario	Year			
	1996	2010	2030	2050
Total industrial roundwood supply	1,490	1,872	2,400 ?	3,100 ?
Forest plantation supply potential				
Scenario 1	370	560	600	600
	(25%)	(30%)	(25%)	(19%)
Scenario 2	370	560	700	800
	(25%)	(30%)	(29%)	(26%)
Scenario 3	370	620	1,100	1,430

	(25%)	(33%)	(46%)	(46%)

DISCUSSION

The above analysis suggests that both the demand for wood and wood products and the availability of wood and other fibre supplies will increase by about 25% over the period 1996-2010 and that markets will clear without any major increases in price. It also suggests that this increase in supply will be broadly within the productive capacity of the world's forests and other fibre supply sources. However, the situation will vary between countries, regions and different supply sources. For example, Africa and some parts of Asia will have to continue to use a wide range of non-forest supply sources to meet future demands and large high-quality sawlogs are likely to become increasingly scarce in some regions, such as Africa, Southeast Asia and the Pacific islands.

Although, in a broad sense, the prices of finished wood products, such as paper and sawnwood, are not expected to rise significantly, there may be upward pressure on the prices of certain types of industrial roundwood (typically the premium grades). However, the availability of cheaper wood and non-wood substitutes will limit the scope for price increases and it can be expected that these cheaper sources will continue to substitute for higher value roundwood inputs.

Possible future changes in supply sources

In many countries, there will probably be a general move away from using forest resources for wood and fibre supply towards using other sources of supply. The greatest change is likely to be an increased use of wood processing residues and recycled fibres in the product input mix. This shift will be supported by the high forecast rates of growth in demand for paper and reconstituted panel products, where such inputs can be used. In some less developed regions, the decline in forest resources will also result in much greater use of trees outside of forests as a source of future wood and fibre supply.

Future supply patterns are also likely to change within forests. The next 10 years or so will see large areas of industrial forest plantations established with fast-growing short-rotation species (for pulpwood production) come on stream in the Southern Hemisphere. Greater areas of older forest plantations (established for sawlog production) will also start to mature in some countries. Supply from these existing plantations is therefore, expected to increase in importance by the year 2010. Beyond this year, the future contribution of forest plantations to overall industrial roundwood supplies will depend upon the rate at which new planting is continued. It is expected that future new planting may proceed at something like the rates assumed under scenarios 2 or 3, suggesting that supply from forest plantations will probably continue to increase in importance in the longer term.

In contrast, it is expected that very few countries will be able to significantly expand supply from natural forests, without considerable investment in silviculture. Indeed, it is quite likely that larger areas of natural forest will be placed into legally protected areas. This should have a marginal effect on supply potential, because many of the areas likely to be chosen for preservation are not currently available for wood supply anyway. However, harvesting intensity in the remaining exploitable natural forest might also fall for two reasons. Firstly, environmental concerns may cause countries to modify existing harvesting regulations to reduce the volume of timber that may be felled in a given area; and secondly, stocking levels may fall anyway as forest operations start to move out of virgin forest and

into secondary forest. These factors cast some uncertainty over the forecasts of future potential industrial roundwood supply presented above, but it is worth stressing that this uncertainty is largely one-sided in that, if these changes occur, they will both tend to reinforce the expected move away from supply from natural forests towards supply from forest plantations and non-forest supply sources.

Technological change has been incorporated into the supply and demand forecasts presented above for the pulp and paper sector only. Here it is expected that the proportion of wood pulp in the total fibre furnish will continue to decline from its current level of 56% to below 50% by 2010. However, other technological changes may also occur in the future. Firstly, improvements in harvesting practices have the potential to increase roundwood recovery and reduce logging residues in many of the world's forests. Similarly, better mill recovery rates could significantly reduce the amount of roundwood required in manufacturing. Associated with this, residues could be used more effectively to meet the demands of other wood processors. A third technological change that might occur is an increased move towards the greater use of reconstituted panels as a result of increasing scarcity of large diameter logs and technological developments in construction and other wood-using industries. None of these improvements in technology have been included in the forecasts, but they could all have a significant downward impact on future industrial roundwood supply and demand.

Policy implications

The preceding analysis has presented some broad indications of changes in forest products supply and demand that will probably take place in the future. However, it is important to note that there is a contrast between the supply and demand components of this analysis. On the demand side, the forecasts are driven by factors such as economic growth, that are largely outside the control of forestry policymakers. On the supply side however, much will depend upon the choices that are made by forestry policymakers in the near-term. In particular, the pattern of future wood supply will depend upon policy developments in the following three areas.

Prices. Prices are a powerful indicator of scarcity; when fixed artificially, they can lead to serious misallocation of investment and resources. About 40% of the world's timber supply comes from private forests and probably about the same proportion of supply is sold in competitive markets. However, governments control the pricing of wood extracted from the remaining (mostly natural) forests and the price of this wood is often kept low to stimulate industrial development. This underpricing may satisfy certain development objectives, but it often leads to undesirable effects. For example, it discourages efficiency in harvesting and processing, reduces the incentive to invest in forest plantations and places alternative suppliers (such as smallholders and recyclers) at a disadvantage. Therefore, better designed pricing policies will be essential to stimulate the development of a wider variety of supply sources such as forest plantations and encourage improvements in harvesting and processing efficiency.

Support to forest plantation establishment. The above analysis has shown how the future supply of wood from forest plantations will, in the long run, depend upon the rate of new planting. In turn, the rate at which new planting is sustained will depend upon the support given to new planting by governments. Many countries currently support new planting with a range of measures including: direct subsidies; favourable tax treatment; extension activities; and state planting. Even in countries

without direct measures, the rate of new planting is affected by their general land use policies and their level of support to other sectors such as agriculture. The rate at which new planting is sustained will depend upon the continuing availability of suitable land for new planting and the extent to which countries continue to pursue these policies.

Human resource development. In many countries, forestry is a labour intensive activity. However, in order to increase efficiency (as suggested above) and meet the growing demand for better management and harvesting standards, the level of forestry skills in many countries will have to be greatly increased. This is a large task given the number of people employed in the sector. For example, Poschen (1997) estimated that industrial forestry accounts for approximately 1 million full-time equivalent (FTE) jobs in developed countries and 2.7 million FTE jobs in developing countries. Better training in forest plantation establishment techniques could also yield significant improvements in plantation supply, which is currently well below what could be achieved because a significant proportion of newly planted areas (particularly in tropical countries) fails shortly after planting.

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