Development of Eucalyptus Plantations - an Overview[1]

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Summary

The rate of forest plantation establishment has increased sharply in the past decade, particularly in Asia and the Pacific, and species of *Eucalyptus* have been among the most important components of such plantation programmes. The rate of deforestation has also increased sharply in the same period, and although the reported figures suggest that output from plantation expansion may keep pace with forest loss, nevertheless plantations cannot provide the full range of goods and services of the natural forest. There is, furthermore, doubt about the reliability of reported plantation area figures. Nevertheless the eucalypts have great potential for wood production as well as for the provision of some services, which could be increased through tree improvement or biomass plantations. Plantation programmes could be promoted through the use of incentives, as has happened elsewhere in the world. No plantation programmes, with *Eucalyptus* species or any other, can succeed, however, without awareness of the political processes necessary for success, including reliable information, participation in decision-making and management by rural people and careful planning and evaluation of the social consequences of environmental or economic effects.

Introduction

Global demand for all wood products is increasing, but the forest resources of the world are decreasing. Total world roundwood production is predicted to grow by 1.9% yearly, to reach 4.1 billion cubic metres by the year 2000 (Gauthier, 1991), and by the year 2025 it may be 6.6 billion cubic metres (Sharma, 1992). Some of the demand will be met from managed natural forests but that resource will have been diminished by an unknown but probably considerable amount due to forest destruction and degradation in the tropics.

Deforestation has been particularly severe in Asia and the Pacific. FAO's recently-completed Forest Resource Assessment of the tropical countries (FAO, 1993a) estimates that the rate of deforestation in the region between 1981 and 1990 was 3.9 million ha per year, or 1.2% yearly. While the amount of forest lost is less in Asia and the Pacific than in Africa or Latin America and the Caribbaean, the rate is higher and the resource base is appreciably lower (see Table 1, Annex 1).

The difference between supply from the natural forests and demand must be met from planted trees. Trees in plantations have considerable production potential. This is illustrated by such arresting statements as the extrapolation that an area of 150 million ha of fast-growing plantations, or 1% of the world's surface, could provide the present global demand for all types of wood (Wilson, 1993).

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[1] Ball, J.B. (1995). Development of Eucalyptus Plantations - an Overview. Proceedings of the Regional Expert Consultation on *Eucalyptus,* Bangkok, Thailand 4-8 October 1993. Vol .I. pp.15-27

Several countries have already invested heavily in forest plantations to meet the demand for some forest products. Chile, New Zealand, Brazil, Spain and Portugal are examples of countries with plantation programmes aimed at the export market, and the eucalypts are important components of the programmes especially in the last three mentioned. Plantations in both Brazil and Argentina, for instance, produced 60% of the country's industrial roundwood but comprise only 2% of the forest area, (Pandey, 1992) and Brazilian exports accounted for 2.8% of the world market for pulp and paper in 1988 (Gauthier, 1991).

If the solution to the problem of wood supply is so simple, one wonders what are the problems to prevent it from being put into effect? Unfortunately there are many constraints. Shortage of land that is both available and sufficiently fertile is one, shortage of money and the weakness of existing institutions are others. These could be overcome if the will is there. Unfortunately the politics[2] of plantations are the main and intractable constraint to their development, and in no case is it more so than with the use of species of the genus *Eucalyptus* in plantation programmes.

The objectives of this contribution to a joint paper on the eucalypts in the south east Asian region are to put the growing of the eucalypts in their global perspective, to draw attention to the need for data but also to the dangers of over-generalization concerning the hazards of growing plantations of the genus, to identify some new trends in forest plantation management and objectives and to stress the need for an involved and informed public in the political process which leads to plantation development.

Area of Eucalyptus Plantations[3]

Plantation Areas in the Tropics (Table 2, Annex 1)

During the period 1981-90 the area of forest plantations in the tropics is reported to have increased by an estimated 2.6 million ha yearly, to reach a total gross area of 43.8 million ha. About 85% of that gross area was established in just five countries: India, Indonesia, Brazil, Vietnam and Thailand. It is relevant to the theme of this meeting that four of those five countries lie in Asia. Over 60% of the gross area of the plantations was described as "non-industrial" and 10 million ha, or nearly one quarter of the gross area, were planted with one genus, the *Eucalyptus*.

Asia and the Pacific Region (Table 4, Annex 1)

The increase in the gross global area of forest plantations occurred mainly in Tropical Asia and the Pacific during the period 1981-1990, at the rate of 2.11 million ha/year (or 81% of the global increase in forest plantations during the period). If this this gross area represents new plantations, and not just areas where plantations have been harvested and replaced with plantations (either of the same of a different species), and if it has adequate stocking, then it is just over half of the area deforested (see above). It appears that future outurn from the gross area of plantations could more than replace the potential for wood production that has been lost. But there are a lot of proviso's.

[2] The Concise Oxford Dictionary defines politics as the "science and art of government" while Webster's Ninth Collegiate Dictionary includes "the total complex of relations between people in society". Both may be illustrated by the phrases "Politics is about power" and "Politics is the art of the possible".

[3] The source of the information on area figures of tropical plantations, unless otherwise stated, is Pandey, 1992

Have these new plantations survived? Have they been maintained? Will they yield as much as was planned? Nor should it be forgotten that they cannot provide the full range of goods and services that came from the natural forest.

The area of Eucalyptus plantations in Tropical Asia and the Pacific was 5.2 million ha in 1990, or just over half of the global total for the genus (Table 3, Annex 1). Most of that area was in India where a total of 4.82 million ha of *Eucalyptus* species were reported, and most of the plantation area in India and elsewhere were planted for non-industrial outputs (see below, Incentives).

Species of eucalypt are the most common constituent of forest plantations in Tropical Asia and the Pacific. The area of pines in 1990 was reported as 1.25 million ha and the area of teak was 2.03 million ha. In considering the non-forest plantations, the area of rubber in Asia in 1990 was estimated as 7 million ha, of coconut as 4 million ha and of oil palms as over 2 million ha (Pandey, 1992). None of the considerable areas of other species in forest plantations, or of non-forest plantations, have caused the furore evoked by the eucalypts.

New Trends in Forest Plantation Objectives and Management

Bio-mass

The carbon released as carbon dioxide on burning as fuelwood can be sequestered in the plantations that replace the original fuel source. The growing of short rotation biomass is therefore being investigated in several countries to provide fuelwood as an alternative to fossil fuels or nuclear energy. Short rotation biomass plantations could also be used as the raw material for reconstituted wood. The trials are of particular interest for developed countries where farmland is being taken out of agricultural production. Most development in this field has been in the use of members of the Salicaceae (poplars and willows) but *Eucalyptus* species offer potential for this purpose (although not necessarily in the same climatic zones as the poplars and willows). The crops are typically grown on very short rotations of two to three years, at close spacings of about 1 metre.

The relevance of biomass plantations to countries of the Asia Pacific Region is in their objective of the production of undifferentiated biomass and the use of techniques that are closer to agriculture than to forestry in the intensity of management practice. Where land is in short supply and the product is to be used for forms of reconstituted wood or for fuel then the cultivation of forest tree species as an agricultural crop may be appropriate. At the same time even such short rotation tree crops can, with proper management, provide many of the services of conventional forest plantations, such as shelter, erosion control and cover for animals and birds.

Tree improvement

More intensive use of all types of land will be necessary in several countries of Asia in the future because there is little scope for horizontal agricultural expansion - even at the expense of natural forest. Some of the inputs for vertical expansion are expensive, such as fertilizers, while others are both expensive and potentially hazardous, such as fungicides or insecticides. Tree improvement on the other hand offers benefits that are low in unit costs but potentially very high in returns. Tree improvement, including species and provenance selection, also offers the means to develop or identify tree species that are adapted to sites, such as salt-affected soils, that are not at present utiliseable.

There have been several tree breeding programmes with *Eucalyptus*, which have given impressive results. They have included the clonal plantations of Aracruz (Brazil) and Pointe Noire (Congo). At Aracruz yields of 28 m^3/ha/year were obtained from the first plantations, mainly of *Eucalyptus grandis*, which were started in 1967 with seed from unselected local sources. A tree improvement programme, which identified suitable provenances and spontaneous hybrids for fast growth and resistance to pests and diseases was started in 1971; this has increased the increment to 45 m^3/ha/year and the pulp yield. Hybrids of *E. grandis* with *E. urophylla* have, on certain sites, attained growth rates of 70 m^3/ha/year. Selection and breeding for improved stem form and branch characteristics, couples with clonal forestry practices, have further increased gains and have also reduced logging costs (Campinhos, 1993).

Clonal planting stock is used in the Pointe Noire plantations of *Eucalyptus tereticornis*, *E. urophylla*, and hybrids. Originally this scheme used a smaller pool of clones and over half of the area was established with just five clones (Martin *et al*. 1989); now more clones are used since the dangers of exposure to increased risk of devastating insect or disease attack with so few clones were recognised and the genetic base was widened through "natural" crossing of *E. urophylla x alba* and *E. tereticornis x grandis* (Martin 1991) and controlled crossings of *E. urophylla x E. grandis* and *E. urophylla x E. pellita* (CIRAD, 1992).

Both of the examples above stress the need for breeding for insect and disease resistance as well as production and technical properties. A search of a recent comprehensive review of pests and diseases of forest plantations in Asia and the Pacific Region (FAO, 1990) shows few serious outbreaks of insect attack or of diseases on *Eucalyptus* species, except for termite attack to roots reported from several countries. This lack of pest or disease problems is fortunate, but is no cause for complacency.

Genetic manipulation offers the potential for more precise improvement or alteration of specific characters. The BIOGENIE research programme which is included in the tree improvement acativities of Cellulosas de Asturia S.A. (CEASA) aims to differentiate the genome of *Eucalyptus* as a basis for the selection of the best fibre properties in order to improve pulp and paper quality (Wilson,1993).

Much of the planting of Eucalyptus in the Asia and Pacific Region is in non-industrial plantations (see Incentives, below). The improvement of the eucalypts through tree improvement will be important to non-industrial plantation programmes in order to develop stock that is not only high yielding in terms of wood and of pulp but also shows plasticity in its reaction to site quality or establishment technique - or in other words, it must be tolerant of a certain amount of neglect, to which species of the genus are particularly susceptible. The development of *Eucalyptus* species tolerant of salt affected soils could have important applications in the Asia Pacific Region, as resistant varieties could be used not only to use or even reclaim land affected by salt but also could be irrigated with brackish water. The problems and potentials of salty soils for tree growing have recently been reviewed in Allen *et al*. (1993).

Whatever the approach to tree improvement, there is no substitute for a sound tree breeding strategy which includes both improvement and genetic conservation, a point emphasised in recent reviews of new and traditional tree breeding techniques (Bisoffi, 1993; Palmberg-Lerche, 1993 and Annex 2)

Incentives and ownership

Various forms of incentive have been used to encourage the participation of the private sector, either as individuals, communities or organizations, in plantation programmes. Such incentives range from supplying seedlings, either free or at subsidised prices, or the provision of technical advice, to tax breaks, relief from property or transfer taxes or from the payment of taxes on capital goods. It should be noted, however, that in Europe "Tax concessions have sometimes proved to be very effective [in increasing afforestation] ... [they] are, however, a much blunter instrument of policy than direct assistance in cash or kind" (Hummel and Hilmi, 1989),

Plantations in the tropics described as "industrial" constitute about 35% of the gross area, of which more than one half are in the Asia and Pacific Region. Typically they are established for the provision of pulpwood or saw timber. Industrial plantations in this region total over 9 million ha or 28% of the regional gross area. Here and in Africa they are mainly owned by the state or public sector but in tropical America they are owned by private companies or individuals. This situation arose in tropical America largely through the financial incentives offered for forest plantation establishment in Brazil and other countries which were subsequently discontinued for a number of reasons.

The future development of industrial roundwood plantations in Asia and the Pacific Region is expected to involve the private sector much more than in the past, particularly through outgrowers[4]. Shortage of land will generally restrict any great increase in the proportion of large-scale forest plantations in the region. But there are some exceptions such as Indonesia, where it is proposed to convert 4.4 million ha of unproductive forest land into productive industrial plantations by the year 2000. *Eucalyptus* species will not necessarily be chosen as the main species for use by all outgrowers or in all large scale plantations; other species such as *Acacia mangium* are increasingly being used.

Non-industrial plantations (community and social forestry) have been established on more than 23 million ha in the Asia and Pacific Region, or 72% of the regional total (Pandey, 1992). Typically these plantations are established with the assistance of free seedlings or technical advice. Up until now there appears to have been no direct financial or fiscal incentives for plantation establishment in the region, although that situation may now be changing, for instance in Viet Nam and in Cambodia. Species of *Eucalyptus* will be chosen for many non-industrial plantations, particularly those grown in blocks.

The involvement of the private sector, particularly where incentives are provided for afforestation programmes will alter but will not necessarily diminish the role of the public sector. The need will be for checking that the incentives are used for the intended purpose, that laws protecting the environment are obeyed and for evaluation of the social, economic and environmental effects of the incentives.

The Need for Information

[4] An outgrower is one who grows the raw material for central processing, as in for instance the tea industry where small landowners grow tea on their farms which they pluck and sell to the tea factory. Often the outgrowers are assisted to purchase plants, fertilizers, insecticides etc, the cost of which is deducted from the price paid for the crop, and sometimes the outgrowers may share in the profits of the factory. The concept has been extended to other crops, including wood.

The data given above on the global and regional state of Eucalyptus plantations have generally quoted reported, gross figures for area. It is most unlikely that they represent the actual areas. Pandey (1992) gives a *tentative weighted average* (his italics) for successful establishment in the Asia Pacific Region of 61%, with a standard error of ± 6% at P.05. In other words there is 95% probability that the actual forest plantation area in the Asia Pacific Region lies between 17.7 million ha and 22.8 million ha. If the same reduction factor of .61 is used for the average annual plantation area established then the area is reduced from 2.1 million to 1.3 million ha, and the net area of Eucalyptus plantations is about 3 million ha. But in fact the reduction factor is itself unreliable, since the weighted average is based on only 36 published survey and survival reports from nine of the 19 countries of the region, of which the surveys were done in 18% of the total plantation areas. Some of the surveys were done through questionnaires, not by physical measurement, and these must be liable to error. Furthermore, it is known that some areas of non-industrial plantations were not included; for instance Bangladesh omitted about
300 000 ha of homestead plantations from the reported area of plantations, which must make significant contributions to fuelwood and even sawlog needs.

There is thus no doubt that the area figures are highly unreliable, but for some other parameters such as yields, increments, costs or economic or social benefits the information is just as unsound or even absent altogether, although possibly available locally. The absence of monitoring or evaluation on a national scale is surprising, since these plantations represent a considerable national investment not only directly into the plantations that have been established by the public sector and the cost of the incentives that have been provided, but also in the land and labour of small farmers in the non-industrial plantations. It is hoped, through the reviews commissioned by FAO for this consultation, through the Country Statements submitted by 14 countries attending the consultation, and through the recommendations of the meeting concerning data collection, that the situation concerning the status of plantations of *Eucalyptus* plantations can be improved in the future.

Economic and Social Effects of Eucalyptus Plantations

FAO's Forestry Paper "The ecological effects of Eucalyptus", published in 1985, (Poore and Fries, 1985) was concerned with the environmental effects of Eucalyptus plantations, although it recognised that environmental effects had social consequences. The economic and social effects are now seen as being the consequences not only of the effect of Eucalyptus plantations on the site and its environs but also of political decisions affecting the forest sector and in particular the supply of wood for industry.

The objectives of political interventions in the forestry sector are generally to increase the forest resource through the establishment of plantations. It is the unintended social consequences, real or imagined, that have led to criticisms of such programmes, and by an irrational leap of presumed logic, to condemnation of the genus *Eucalyptus*.

In reading the literature on forest plantations worldwide there is increasing emphasis on sustainable land use practices. In this connection plantations must be considered not just for the production of timber or fuelwood but for other outputs and for the services that can be provided by trees. While the eucalypts have many benefits, including fast growth and the ability to coppice, their harvest is largely limited to woody products such as fuelwood, poles, pulpwood and timber although honey and oils are also produced in some instances. Their services include protection of

crops and of the soil, but their fast growth often leads to competition with adjacent crops and the elimination of the undergrowth covering the soil - an effect compounded by the practice in many countries of collecting the litter beneath the trees.

This is not to say that forestry in sustainable land uses is not possible with Eucalyptus plantations but it is necessary in planning any plantations to be clear about their objectives and of the consequences of selecting a particular tree species. If species of Eucalyptus meet the criteria of the objectives while not creating unfavourable ecological or socio-economic effects then the plantations should be evaluated against those criteria, not against some other list of potential benefits that lie outside the objectives. "Most ecological effects can only be evaluated with reference to what society wants" (Poore and Fries, 1985). If society wants industrial roundwood cheaply, quickly and of a particular technical specification, then plantations of Eucalyptus may well be the answer, with other goods and services provided from elsewhere. If society wants multiple benefits from the same piece of forest land, then the eucalypts are not likely to provide the answer, and society must select another option - and be prepared to pay the cost.

Recognition of the need for sustainable forestry practices is leading to the involvement of people in plantation programmes, particularly to participating in them, to better matching of species and provenances with site, to establishment practices that are less damaging to the soil, such as the use of lighter equipment or the elimination of fire in site preparation, to quantification of benefits, such as employment or the provision of social services, to measurement of the effects of plantations on the environment, particularly on ground water and soil fertility, and to evaluation of the plantations in the local or national economies, rather than from the point of view only of financial return.

The participation of people in rural development through forest plantations is now emphasised more strongly than ever. Examples include the outgrower scheme established by the Paper Industry Corporation of the Philippines for the provision of up to one third of its pulpwood requirements, where the company provides seedlings (including *Eucalyptus deglupta*), loans and advice (Bass, 1992). Another example of the involvement of outgrowers is the CEASA scheme in Spain, which in its first year involved 500 farmers. The scheme includes the extension of agroforestry techniques, and the production of honey, oil and timber as well as pulpwood (Wilson, 1992).

Conclusions

Forest plantations will be essential to meet the growing demands for goods and services from forest resources. *Eucalyptus* species have the potential to be an important component of such plantation programmes in the temperate, sub-tropical and tropical zones. In the Asia Pacific Region *Eucalyptus* will be used along with conifers and other broadleaves in industrial and especially in non-industrial plantations. The creation of such plantations and the choice of species will depend on political forces, in the broadest sense of the power of public opinion on government decisions.

The Asia Pacific Region is already the most important of the tropical zones in terms of plantation area, rate of planting and use of *Eucalyptus*. This situation is likely to continue, emphasising the need for research and data collection to provide a solid base for future plantation programmes, not only of the eucalypts. Such research and data collection should not be confined to ecological aspects, important as issues such as water use and compeitition may be, but must recognise the

social and economic consequences of environmental effects.

New developments in the growing tree crops on short rotations and at close spacings for biomass offer opportunities for more intensive land use, and tree improvement programmes could result in higher yields of interest both in industrial and non-industrial plantations. The latter will include tolerance of infertile, including saline, sites.

Financial incentives, as opposed to free seedlings or advice, seem to be little used in the region at present, although this may increase. If this happens then the public service will have to strengthen its ability to monitor and to evaluate plantations developed by the private sector.

Existing technical knowledge is sufficient to establish *Eucalyptus* plantations to provide goods and services on a sustainable basis so long as species and provenance is matched to site and sound forest and land use management practices are followed. The participation of the involved public (including people living in or off the forest or woody vegetation) in decision making and in management is frequently omitted when new plantations are planned, often leading to unforeseen social consequences.

These consequences are as yet still inadequately quantified, and even data on the areas or growth rates of *Eucalyptus* are scarce and where available, generally unreliable. Sound, unbiased data obtained from properly planned research is fundamental to the political process leading up to the establishment of *Eucalyptus* plantations.

In considering objections to *Eucalyptus* plantations due to their effects on the environment or society it is important to identify whether the objections are to the effects of *Eucalyptus* as species, to the effects of the plantation or whether the complaints about the species are in fact concealing other political grievances. In discussing the objections of farmers to the Thai government's plantation programme it has been stated that "Farmers will not lightly cede rights to land and livelihood, and they have cited the supposed environmental disbenefits of *Eucalyptus* to crusade against the [government's plantation] policy. The battle is not about *Eucalyptus*, however. It is about power" (Sargent and Bass, 1992).

The final conclusion therefore must be that plantation programmes are political issues, and as such are about people, about power and about persuasion. The selection of one or more particular species for such programmes, whether one of the eucalypts or another, may be a technical matter, related to objectives and to site, but it will in the final analysis also depend on the foresters' ability to sell the technical package to the public and to their representatives.

Annex 1

Area Figures

Table 1 - **Estimates of Forest Cover and Rate of Deforestation**

Geographic subregion/region	Number of countries	Land area	Forest cover		Annual deforestation 1981-90	
		million ha	1980 million ha	1990 million ha	million ha	% per annum
Africa	40	2 236.1	568.6	527.6	4.1	0.7
Asia & Pacific	17	892.1	349.6	310.6	3.9	1.2
South Asia	6	412.2	69.4	63.9	0.6	0.8
Continental S.E. Asia	5	190.2	88.4	75.2	1.3	1.6
Insular S.E. Asia	5	244.4	154.7	135.4	1.9	1.3
Pacific	1	45.3	37.1	36.0	0.1	0.3
Latin America & Caribbean	33	1 650.1	992.2	918.1	7.4	0.8
Total	**90**	**4 778.3**	**1 910.4**	**1 756.3**	**15.4**	**0.8**

Source: FAO 1993a

Table 2 - **Forest Plantations in the Tropics, 1980 and 1990**

Region	Number of countries	Total areas by categories in million ha						Average Annual Rate (000 ha)
		1980			1990			
		Industrial	Non-Ind	Total	Industrial	Non-Ind	Total	
Tr. Africa	36	0.96	0.76	1.7	1.37	1.62	3	127
Tr. America	26	2.55	2.36	4.9	5.10	3.54	8.6	373
Tr. Asia	19	3.57	7.60	11.2	9.16	23.14	32.3	2 112
Total	**81**	**7.1**	**10.7**	**17.8**	**15.6**	**28.3**	**43.9**	**2 612**

Source: Pandey, 1992

Table 3 - **Estimates of Reported Areas of Main Species (million ha)**

Region/Species	Eucalypts	Pines	Teak	Acacias	Others	Total
Tr. Africa	0.79	0.61	0.145	0.25	1.2	3
Tr. America	4.07	2.78	0.015	-	1.77	8.6
Tr. Asia & Pacific	5.20	1.25	2.03	3.15	20.68	32.3
Total	**10.06 23**	**4.64 10.5**	**2.19 5**	**3.40 7.7**	**23.65 53.8**	**43.9**

Source: Pandey, 1992

Table 4 - **Reported Plantation Areas, Tropical Asia-Pacific Region ('000ha)**

Countries	Up to year end 1980			Up to year end 1990			Average Annual Rate
	Industrial	Non-ind.	Total	Industrial	Non-ind.	Total	
Bangladesh	128	32	160	189	146	*335	
Bhutan	2		2	5		5	
India	1 536	2 950	4 486	5 670	13 230	18 900	
Nepal	19		19	55	25	80	
Pakistan		160	160	88	152	240	
Sri Lanka	112	18	130	180	18	198	
South Asia	1 797	3 160	4 957	6 187	13 571	19 758	1480
Laos	4		4	4	2	6	
Myanmar	30	25.7	55.7	222	112.8	334.8	
Thailand	63	272.4	335.4	377	378.5	775.5	
Vietnam	60	1340	1400	600	1500	2100	
C.S.E. Asia	157	1 638.1	1795.1	1 203	1 993.3	3 196.3	140
Indonesia	1 446	2 564	4 010	1 430	7320	8750	
Malaysia	26		26	115.5		115.5	
Philippines	65	235	300	60	230	290	
Ins.S.E. Asia	1 537	2 799	4 336	1 605.5	7550	9155.5	482
Fiji	40		40	90.2	13.8	104	
N. Caledonia	7		7	10		10	
Papua N. G.	17	5	22	35	7.6	42.6	
Samoa	2		2	6		6	
Solomon Is.	17		17	24.6		24.6	
Vanuatu	0	0	0	1	1	2	
Pacific Is.	83	5	88	166.8	22.4	189.2	10
TOTAL	**3 574**	**7 602.1**	**111 176.1**	**9 162.3**	**23 136.7**	**32 299**	**2 112**

*Excludes about 300,000 ha of homestead plantations. Source: Pandey, 1992

Annex 2

A Note on New Techniques in Tree Breeding

The following extract sumarises the potential of new techniques in tree breeding that are relevant to the *Eucalyptus* (Palmberg-Lerche, 1993 and FAO, 1993b):

> "In the short term, for species with known biology and variation patterns, opportunities exist for technology replacement in the incorporation of micropropagation into integrated multiplication systems for intensively bred species, and in the use of molecular markers in genotype verification. For presently biologically less well- known species opportunities exist for the use of markers in studies of genetic variation and breeding systems. In the longer term, significant applications of new technologies are likely.
>
> Major research priorities include the acquisition of better understanding of molecular genetic processes in forest trees, particularly those underlying adaptation, and their manipulation. Continuation of research on markers and genetic engineering with model species, will lay the foundations for later application of these techniques to both industrial and non-industrial species. For intensively bred species, development of somatic embryogenesis and artificial seed technologies, of cryopreservation as a means of preserving juvenility, and of techniques for the genetic engineering of lignin reduction (in species grown for pulp), will be useful targets for continued research. Genetic engineering of sterility will be an important objective likely to facilitate later deployment of transgenic plants. The development of simple micropropagation protocols for species for which these are not already available will also be of value."

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