Site, Technology and Productivity of Teak Plantations

Regional Seminar - Conclusions and Recommendations

TEAKNET Asia Pacific Region

TEAKNET's primary aim is to strengthen interaction among all those concerned with the conservation and sustainable management of teak-bearing forests and plantations through sharing of information and promoting collaborative efforts to deal with common problems. More specifically the TEAKNET objectives are:

i. To facilitate the exchange of technology and information on tree improvement, silviculture, management, harvesting, processing and trade of teak;
ii. To assist in the exchange of genetic material and plant and wood samples and to standardize trials and methods which will enable international comparison; and
iii. To promote collaborative studies on critical areas that are of common interest to member countries and institutes.

FORSPA

The Forestry Research Support Programme for Asia and the Pacific (FORSPA) is designed to enhance country capacity in forestry research. At the regional level, it aims to develop sustainable networking arrangements through the Asia Pacific Association of Forestry Research Institutions (APAFRI). Country capacity building efforts are focused on research strategy formulation and planning, human resource development, facilitating access to information and promoting collaborative arrangements between institutions in the Region. Funded by the Government of The Netherlands, FORSPA is implemented by the Food and Agriculture Organization of the United Nations.

Forest Resources Department

Forest Resources Department is established under the Faculty of Agriculture, Chiang Mai University. The Department has initially been designed for the development of post graduate (M.Sc.) course on forest resources and conservation. The field of specialization covers sustainable forest resources management, tropical forest ecology and biodiversity, plantation silviculture and community-based forest resources management. As a part of the Highland Development Research and Training Centre of the Faculty, the Department also conducts regional, national and local training on its specialized areas in collaboration with various national and international agencies such as DTEC, FAO/FORSPA, UNDP, ICRAF, JICA, DANCED.

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CONCLUSIONS AND RECOMMENDATIONS

REGIONAL SEMINAR ON "SITE, TECHNOLOGY AND PRODUCTIVITY OF TEAK PLANTATIONS"

BACKGROUND TO THE SEMINAR

The Regional Seminar on "Site, Technology and Productivity of Teak Plantations" was held from 26 to 29 January 1999 in Chiang Mai, Thailand with the following objectives:

- To review the current state of technologies and practices for establishing and managing teak (*Tectona grandis*) plantations in the Asia-Pacific Region;
- To review the information on productivity of teak plantations under different conditions and management regimes and to assess the linkages of site, technology and productivity; and
- To identify the main issues of improving management of teak plantations and to develop a framework for collaborative studies and technology improvement.

The seminar was particularly relevant and timely in the context of:

- The importance of teak as a tropical hardwood species fulfilling the demand for high value timber;
- The rapidly expanding interest of the private sector (including plantation companies, farmers and small-scale growers) in investing in teak plantations;
- The expansion of teak into new areas far outside its natural habitat with risks of stress to the trees and consequent exposure to insect or pest attacks or effects on timber quality; and
- The often highly optimistic claims of productivity and financial rate of return made by some promoters for investment in teak plantations, misleading the public and investment institutions.

More than 100 participants from 22 countries attended the seminar. It brought together representatives of the private sector, government departments, research institutes, international agencies, networking organizations and investors.

Although the focus of the seminar was initially on the Asia-Pacific Region, the importance of the topic attracted participants from Africa, Central and South America and Europe, enriching the exchange of experiences and the discussions. A global overview by the Food and Agriculture Organization of the United Nations (FAO) set the stage of the seminar by outlining the historical trend in the expansion of teak plantations, productivity estimates and the projected area and volume of teak that may be available during the next 50 years, as well as some of the main issues. Country papers from the various teak growing regions illustrated the wide range of experiences in teak cultivation and management. Specific theme papers discussed tree improvement, different aspects of mass production of planting stock, the incidence of teak pests and their control, the utilization of small dimension wood, and productivity and economic aspects of teak plantations.

Important issues that emerged from the papers were discussed in detail in a final plenary session, drawing upon a note prepared by a drafting committee.

Appendix

**Recommendations**

1. Improving access to information
2. Technology and productivity
3. Products, markets and economics
4. Policies and incentives
5. Regional and global facilitation

**Appendix**
This report summarizes the important findings and recommendations of the seminar. A companion volume consisting of all the papers presented during the seminar is being produced separately. The conclusions and recommendations are divided into four major theme areas:

1. technology and productivity;
2. utilization, marketing and economics;
3. policies and institutions; and
4. regional and international support mechanisms.

IMPORTANT FINDINGS

Technology and productivity

Current teak plantation program

The estimated net area under teak plantations in 1995 was 2.25 million ha. Most of the annual reported planting of 100,000 ha is accounted for by replanting after harvests in existing plantations. Hence, the net addition in area has been rather low. Notwithstanding that teak is one of the most important hardwood plantation species in the tropics, reliable estimates of total area, annual planting rates and actual productivity are not available or sketchy at best.

The area under private sector management is expected to increase rapidly as long as teak planting is perceived as a commercially attractive investment

Current teak plantation management is dominated by the public sector, especially government forestry departments or state corporations/enterprises. Private involvement in establishing teak plantations is a recent development and the area under private sector management is expected to increase rapidly as long as teak planting is perceived as a commercially attractive investment. Under clear and favorable tenure conditions, less restrictive policies, and the provision of economic incentives, teak plantings have particularly expanded in small woodlots and homesteads.

The expansion of teak planting in the traditional teak growing countries is limited by the non-availability of suitable sites. Consequently the annual net addition to the area under teak plantations has been rather low during the last few years. Teak plantations also face intense competition from alternative land uses. Future expansion of teak plantations is expected to take place mostly in areas outside the traditional areas, where extensive land is available. Differences in environmental conditions require refinement and development of site-specific technologies and practices.

The state of teak plantation technology

Although there is a long history of teak planting and considerable experience has been gained, relevant information in an easily retrievable and usable form is unavailable. Further, there is a considerable gap between what is known and what is applied. In other words, there are significant barriers to accessing and applying existing information.

Information on the spread of technologies and their effect on productivity is lacking. Systematic efforts to organize existing knowledge and assess progress in the field at the national or international levels are inadequate. Although the technology of teak planting is well understood, public sector plantations are managed under low intensity/low investment regimes, the uptake of research results is poor and known technologies are not effectively applied. The private sector, on the other hand, is keen to apply productivity enhancing technologies to maximize returns on investment.
Estimated net plantation area of teak, by sub-region in 1995 (1,000 ha)

<table>
<thead>
<tr>
<th>Sub-Region</th>
<th>Estimated net area of total plantation</th>
<th>Estimated net area of teak plantation</th>
<th>% of Teak plantation area</th>
<th>Estimated Annual planting</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Sahelian Africa</td>
<td>242</td>
<td>4.02</td>
<td>1.67</td>
<td>0</td>
</tr>
<tr>
<td>East Sahelian Africa</td>
<td>640</td>
<td>14.85</td>
<td>2.32</td>
<td>--</td>
</tr>
<tr>
<td>West Moist Africa</td>
<td>324</td>
<td>87.88</td>
<td>27.1</td>
<td>4</td>
</tr>
<tr>
<td>Southern Africa</td>
<td>790.6</td>
<td>2.80</td>
<td>0.35</td>
<td>0</td>
</tr>
<tr>
<td>Tropical Africa</td>
<td>1896.6</td>
<td>109.55</td>
<td>5.78</td>
<td>4</td>
</tr>
<tr>
<td>South Asia</td>
<td>13222</td>
<td>1099.60</td>
<td>8.24</td>
<td>55</td>
</tr>
<tr>
<td>Continental SE Asia</td>
<td>2382</td>
<td>302.28</td>
<td>12.67</td>
<td>26</td>
</tr>
<tr>
<td>Insular SE Asia</td>
<td>3279</td>
<td>706.01</td>
<td>21.53</td>
<td>12</td>
</tr>
<tr>
<td>Tropical Asia</td>
<td>18983</td>
<td>2107.89</td>
<td>11.10</td>
<td>93</td>
</tr>
<tr>
<td>Tropical Oceania</td>
<td>132</td>
<td>3.03</td>
<td>2.30</td>
<td>0</td>
</tr>
<tr>
<td>Tropical Oceania</td>
<td>132</td>
<td>3.03</td>
<td>2.30</td>
<td>0</td>
</tr>
<tr>
<td>Central America</td>
<td>238.7</td>
<td>22.29</td>
<td>9.34</td>
<td>4</td>
</tr>
<tr>
<td>Caribbean</td>
<td>466.1</td>
<td>8.06</td>
<td>1.73</td>
<td>--</td>
</tr>
<tr>
<td>Tropical South America</td>
<td>5271</td>
<td>2.72</td>
<td>0.05</td>
<td>0</td>
</tr>
<tr>
<td>Tropical America</td>
<td>5975.8</td>
<td>33.06</td>
<td>0.60</td>
<td>4</td>
</tr>
<tr>
<td>TOTAL</td>
<td>26987.4</td>
<td>2253.53</td>
<td>8.35</td>
<td>101</td>
</tr>
</tbody>
</table>

Availability and access to technology varies widely among the teak growers. While the public sector has not taken full advantage of its own research, access to information by private growers is not uniform. In particular small-scale growers and farmers are disadvantaged and have very little access to technology and market information. As a result, the use of inappropriate planting materials and poor management are common amongst this group of increasingly interested producers.

**Site selection and plantation management**

Differences in management objectives, the level of investment and the variations in environmental conditions explain the diversity in production systems and the technologies adopted. This is particularly the situation in the traditional teak growing countries. Although teak can be produced under a wide range of conditions, areas that could support high productivity plantations are limited and face intense competition from a number of cash crops such as oil palm, fruit trees and vegetables. In many countries teak is being planted on degraded land which explains, at least in part, the low productivity of many plantations. Good quality land for planting teak remains scarce.

Most public sector plantation programs rely on low cost technologies. Investment in plantation establishment ranges from US$ 100 to over US$ 1,000 per ha, depending primarily on site conditions and input levels.

**Tree breeding**

Substantial enhancement of desirable attributes (e.g., volume production, stem form) could be achieved through systematic tree improvement followed by mass multiplication. Although significant efforts are being made in these areas, they tend to be fragmented. Shortage of financial resources and high staff turnover hamper long-term systematic efforts in tree improvement.

The advent of tissue culture and other mass multiplication techniques have enhanced the ability to produce uniform planting materials on a large scale. These efforts need to be closely integrated with upstream tree breeding and conservation efforts (including in situ conservation of natural populations, identification of variability in different traits and development of improved clones and clone-site matching) because these
techniques per se are unlikely to confer any lasting advantage. There is no single ‘super clone’ suitable for all sites.

Poor production from seed orchards in some countries do not warrant abandoning planting material production through the seed route. A better understanding of breeding systems and improvement in establishment and management of seed orchards and production areas is required.

Protecting and maintaining natural teak populations (ideally covering the whole range of distribution, including marginal populations in its natural occurrence) are critical to the long-term sustainability of genetic improvement and development of a vigorous plantation program. Coordinated efforts at regional and sub-regional levels are required to identify gaps in the actual coverage of conservation stands.

**Productivity**

While a broad range of productivity rates derived from experimental plots are available, actual estimates for yield under different agroecological conditions and management regimes are sporadic or do not exist at all. Also, the terms ‘productivity’ and ‘mean annual increment’ are being used ambiguously and make comparisons difficult. There is a need to define the precise meaning according to products and the dimensions. Just as crucial is the need for defining the quality parameters.

Mean annual increments (in terms of commercial volume) actually obtained from government plantations range from 2 to 5 m³/ha and are below the potential productivity. Low inputs and poor management coupled with factors like illicit removal, fire, pest infestation and disease outbreaks lead to low productivity even on high potential sites.

Rigorous site selection combined with application of known technologies and improved protection could increase the mean annual increment to 8 to 12 m³ per ha. A productivity of 15 to 20 m³/ha/year even on a short rotation of 20 years should be viewed as the upper limit under the existing state of technologies. Claims of higher production levels should be subjected to careful scrutiny.

**Potential areas for new technologies**

Long-term effects of successive rotations on site productivity are inadequately understood. Although productivity decline has been reported in a few cases, no systematic assessment has been made to understand its causes (which could be attributed to soil erosion, soil mining, fire and other factors). A systematic review of available information is urgently required and should prepare for collaborative studies covering a range of conditions and technologies under which teak is grown under successive rotations. Site management to sustain productivity requires substantial efforts. Intensive site management involving irrigation, soil conservation measures, fertilizer applications including the use of biofertilizers needs further assessment and studies.

Current site quality assessments rely primarily on growth parameters. While this is appropriate in relation to the objective of timber production, a monitoring system for detecting changes in critical site parameters (especially physical, chemical and biological characteristics) should be designed to prepare for timely corrective measures.

Biological control measures to manage pests and diseases (e.g., *Bacillus thuringiensis* application and use of nuclear polyhedrosis virus for control of defoliators) require further efforts, especially to facilitate large-scale application and to overcome resistance to treatment. Furthermore, changes in the pest populations should be monitored regularly, and early warning systems be developed.

### MAI maximum and at 50 years rotation age in m³/ha/year on best, average and poor site classes

<table>
<thead>
<tr>
<th>Country</th>
<th>Best</th>
<th>Average</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAI (max)</td>
<td>MAI (50)</td>
<td>MAI (max)</td>
</tr>
<tr>
<td>India</td>
<td>12.3</td>
<td>10.0</td>
<td>7.9</td>
</tr>
<tr>
<td>Indonesia</td>
<td>21.0</td>
<td>17.6</td>
<td>14.4</td>
</tr>
</tbody>
</table>
Yield tables have been prepared based on inadequate number of sample plots and are provisional.

The potential for integrated pest management (IPM) requires further studies and evaluation. While mixed stands are reported to act as barriers to the spread of infestations, further efforts are required to understand the role of complex mixtures. Some efforts have been made in the past to introduce other species in teak plantations through interplanting/underplanting. But the documentation of these efforts is poor and needs to be upgraded.

Utilization, marketing and economics

Teakwood markets and prices

The limited studies on historical prices for teakwood suggest an upward trend, although no demand and supply assessments have been made at the global, regional or national levels. The products from teak plantations and forests vary in size and quality with wide ranging and uses and, consequently, prices. Further, teakwood prices for the same kind of product vary across different transaction points. Detailed spatial and temporal information on quantity/quality/price relationships is not readily available. Considering the declining supply from natural forests, the long-term prospects for plantation grown teak seems very promising. Property managed teak plantations can generate attractive returns to investment.

Short rotations and small-dimension wood

First time investors in teak plantations are particularly concerned about the end uses and prices of poles and small diameter logs obtained from pre-commercial thinnings and the final harvest. The high proportion of sapwood, variation in physical and mechanical properties, appearance of wood as compared to what is obtained from natural forests and long rotation plantations, and the feasibility of processing/marketing smaller dimensions are critical in making the investment profitable. In areas with a long history of teak plantations, this seems to be less of a problem and diverse demand structures have evolved over time. Utilization technologies have also considerably improved, facilitating the use of small dimension timber.

Apart from this work on conversion technologies, the problem of developing a market, which depends on producing material in sufficient quantities, should not be overlooked. Development of new technologies for processing depends on the scale of production and the perceived long-term return on investments. Considering the experience of utilization technologies for a number of other products (e.g., rubber Wood), supply of adequate quantities is a necessary condition to encourage technology development.

Economic analysis

The few studies available suggest that even with a mean annual increment of 3m³/ha (volume obtained from thinnings and final felling), plantations grown on a long rotation of over 50 years yield a rate of return of over 15 percent. This is largely due to (a) very low initial investment, (b) exclusion of land costs as the plantations are raised on government land (no opportunity cost is assumed), (c) marketability of the products from the early thinnings enabling the recovery of initial investments and (d) the high price of timber obtained from subsequent thinnings and the final harvest.

Teak plantations can be an attractive investment. However, more transparent analyses are essential, including sensitivity analyses that consider the diversity in management and markets to build investor confidence and to prevent speculative investment based on misleading claims.

Certification

Certification of plantations is becoming an important factor. There is a need to raise the awareness of
environmental and social impacts, especially on local communities. Both the public and private sectors should be aware of the certification processes and the measures to be taken to comply with various standards.

Certification of plantations is becoming an important factor.

Current incentives to certification consist of the potential for obtaining higher prices in niche markets where consumers are conscious of the environmental and social aspects of forest management and are prepared to pay a premium price for timber obtained from sustainably managed areas. Often the additional costs involved in certification may not be commensurate with the benefits, especially in the case of small-scale growers. Further, it may take quite sometime for the widespread emergence of consumer preferences for certified timber and the attendant benefits from certification. Whether there is such preference or not, it is important to encourage the adoption of best practices that are environmentally sound and socially acceptable without necessarily going through a formalized certification process.

Other benefits

Intensively managed plantations can provide employment and income to rural communities, especially when local people are able to obtain a fair share of the benefits from the teak plantations. There are however very few studies on the social benefits from teak plantations, in particular on how the benefits to local communities could be enhanced.

As a long rotation species primarily used in furniture, construction and other fixtures, teak could play an important role in carbon sequestration. However, there has been no systematic assessment of the potential role of teak plantations in CO₂ fixation. Studies on this could facilitate the use of carbon offset funds that are expected to be available in the context of the Kyoto protocol.

While teak has a number of positive qualities as a plantation species, care should be taken in testing and validating all claims of its potentials. This will ensure that promoting teak is based on factual information and investors are not guided by exaggerated claims.

Policies and institutions

Enabling policies to promote investment

Existing policies and legislation in several countries are not conducive for the involvement of the private sector in planting teak. The restrictions on felling and transport of teak, purportedly aimed to protect public sector plantations and forests from illegal removal, act as disincentives. Such policies and regulations need to be reviewed and where necessary changed to provide a positive environment for the involvement of private enterprises and farmers in growing teak.

Land tenure is a major factor that influences investment decisions, especially on account of the long-term nature of teak production. Tenure insecurity is a key element to be resolved to provide an enabling environment for promoting private sector involvement in teak plantations.

Direct incentives

Access to relevant information is also an important requisite for promoting investment in teak. It was noted that a number of investors/planters initiate teak plantations without a clear picture of the potential results and the technical and financial implications. Mechanisms for providing reliable information on teak investment are absent or very weak.

Financial incentives are critical to stimulate investments in teak. Current loan financing arrangements are far from adequate to facilitate such investment. Also, there are no mechanisms to link potential investors with growers. This is particularly so in the case of small-scale growers whose access to institutional financing is very limited as credit institutions are reluctant to provide loans for long-term investments.
Tax incentives could play an important role in promoting investment in teak. Teak has a potential for being considered not just as a financial investment, but as a ‘green investment’. Efforts in this direction could facilitate higher investment in establishing and managing teak on a long rotation basis.

**Research and extension**

Most of the current research is fragmented and supply driven. Research institutions have to address the needs of the teak growers. Specific areas that require attention are the long-term sustainability of teak plantations, establishment and management of mixed plantations and appropriate crop combinations suitable for small growers under mixed agroforestry systems.

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**Most of the current research is fragmented and supply driven**

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The linkage between public and private sector research is generally very weak and there is no effective mechanism to facilitate the smooth flow of information in both directions. The role of different players is ill-defined and competing interests often lead to unnecessary secrecy and failure to share information for mutual benefits.

Market information – especially on prices of different qualities and sizes of materials and their changing demand – is not readily available. Although historically teak prices have registered real term increase and the markets are unlikely to be saturated leading to price declines, investors are interested in future scenarios of demand, supply and prices.

**Other support mechanisms**

Currently most investors have no reliable source for obtaining information on all aspects (technical, financial, economic, environmental and social) of teak investment. Misleading information has led to wrong decisions and this has already resulted in a decline in investors' interest. There is therefore a need for developing a mechanism to provide advice on teak investment.

Associations and cooperatives could provide necessary technical support, ‘Information and advice to small-scale growers and assist in marketing of teakwood. Experience of such institutional arrangements in other sectors and for other crops need to be reviewed and, where appropriate, adapted to the needs of the farmers and other growers.

**Regional and international support mechanisms**

**Regional and interregional collaboration**

Coordinated efforts at regional and sub-regional levels are required to identify gaps in the conservation, sustainable management, breeding and enhancement of the species' genetic resources and to avoid possible duplication of work. International collaboration should be strengthened particularly with regard to identifying priority activities most likely to benefit from cooperative efforts. Such activities could include in situ and ex situ conservation of genetic resources, provenance identification and testing, standardization of registration and description of clones, and finalization of common methodologies and procedures to allow comparison of results among areas and countries. Collaborative efforts at regional and inter-regional levels are particularly important for testing different clones for several traits in a variety of sites and conditions and for developing technical guidelines for safe exchange of genetic materials.

National efforts to collect growth and yield data could be complemented through a network of permanent sample plots established under representative agroecological conditions spread over all important teak growing countries. These could provide valuable information on teak under diverse environmental and treatment conditions, and on interactions resource x site x silviculture.

In addition to fostering common issues on resources, there is an urgent need for collaboration in products and
markets, standardization of definitions for collection and disseminating information especially relating to technology, markets, and prices. Such regional collaboration is particularly relevant for standardization of grading rules for teak timber, especially plantation-grown wood and in undertaking outlook studies relating to future demand, supply and prices.

**Networks and associations**

Existing networking arrangements like TEAKNET, TEAK 2000 and the IUFRO Group on Teak have considerable potential to support and strengthen the conservation and scientific management efforts. Their interaction should be strengthened through regular information exchanges.

Although a large number of persons are involved in teak research, technology development and extension, information on who is doing what is not readily available. Networks like TEAKNET could facilitate the availability of such information by developing a directory that could be easily accessed by those in need of the information.

It is necessary to develop a global framework to facilitate investor-grower dialogue and to set standards for best practices, including stipulation DOs and DON'Ts in teak investment. TEAK 2000 could play an important role in assisting the development of a body that could actively promote investment in teak and to mobilize resources.

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*Information on who is doing what is not readily available.*

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**RECOMMENDATIONS**

Based on the above findings the seminar made the following recommendations to strengthen the ongoing efforts on conservation and sustainable management of teak plantations.

**Improving access to information**

**Data and information**

Systematic efforts are required at the national, regional and global levels to assess existing areas of teak plantations and natural stands, to collect data on the trends in the area under teak plantations, and information on the rate of spread of different technologies and their impact on growth rates and production. All the teak growing countries should collect, store and analyze such data and information. Regional and global database’s should be developed and maintained as a collaborative effort by networks like TEAKNET, TEAK 2000 and international organizations like ITTO and FAO (including the FAO Global Forest Resource Assessment Programme).

**Web-site**

A web-site (or network of related web-sites) allowing rapid access and linkages to information on teak should be developed and all information on teak cultivation, management and conservation should be made available in an easily accessible form.

**Records and archives**

Several countries have many years of experience in scientific research and investigation into the growing and utilization of teak. They should be encouraged to review these records and archival materials and to summarize information relevant to present-day challenges.

**Directory of teak experts/consultants**
A directory of experts and consultants on teak should be developed, perhaps by TEAK 2000 in collaboration with networks like TEAKNET, which should be made available for technical and advisory services.

Technology and productivity

Yield tables

Improved national yield tables, that provide growth and yield estimates under a range of site and treatment conditions, should be prepared and made available by concerned countries. A network of permanent sample plots covering the entire range of growth conditions and intensities of management should be established adopting common standards and definitions to facilitate comparison.

Site selection criteria and tools

In view of the critical nature of site on productivity, the criteria for selecting land for teak plantations should be refined, harmonized and widely disseminated.

Long-term strategy for tree improvement

Teak growing countries and supporting institutions should define a long-term strategy for breeding teak taking into account all aspects of long-term tree improvement, including the conservation of natural populations, the exploration, identification and evaluation of provenances and land races which may possess traits of potential value, and progeny and clonal trials. Application of the results would be developed such as mass propagation through seed orchards, propagation through cuttings, tissue culture, etc., in an integrated approach that facilitates continuity and links with other fields.

Conservation of genetic resources

Measures should be taken, as part of the tree improvement strategy, to conserve in situ and ex situ the genetic resources of teak in all countries of its natural distribution or domestication. The genetic base of man-made or secondary populations and alleged land-races should be examined based on historical records and the use of modern techniques like genetic markers. These studies, based on both genecological parameters, common garden experiments and molecular verifiers, should aim at obtaining consistent information on the extent and patterns of genetic variation in both natural and man-made stands.

Seed source identification

All agencies concerned with collection, distribution and use of seeds should adopt a system for the identification and registration of the source of the reproductive material (seed, cutting, pollen, germplasm, etc.). Application of a seed zone classification based on genecological information should be considered in the absence of any other reliable differentiating system.

Management of seed orchards

Efforts to improve management of clonal seed orchards for enhancing seed production should be made, specifically considering the potential of more efficient pollinators, improved understanding of the phenology and reproductive biology of the species and clones, and improving the layout and design of the seed orchard itself.
Progeny and clonal trials

Results from available progeny and clonal trials should be analysed and compared in order to estimate the likely gain from different tree improvement strategies. Multi-site clonal (and progeny) tests should be established in a variety of sites in order to quantify genetic parameters in a way that potential gains can be estimated, and the adaptation of different genotypes to site can be assessed.

Commercial-scale production of superior provenances

Commercial-scale production and sale of so-called superior teak phenotypes for internal use and export already exist. Substantiated and sound information should be provided to the end user on the potential benefits and risks associated with large-scale deployment of genetically identical materials, including ways to buffer potential risks through a mixture of clones and site-matching materials. Attention should be given to site-matching studies as prerequisites prior to starting large-scale planting activities, and to vary site conditions in which superior clones have displayed beneficial behaviour.

Guidelines for the international transfer of teak germplasm should be developed, taking into account international and national regulations and phytosanitary requirements, including legislation on the exchange and utilization of genetic resources. Guidelines are required for purchasers of such material on the need to test transferred germplasm on its new site, especially where that may be very different from the source of the original material and on the need for adequate accompanying records of the source of the material.

Pest and disease management

Although some efforts have been made to develop biological control measures to manage teak pests, efforts to develop practical procedures for large-scale adoption of integrated pest management need to be pursued. The effect of pests on the quantity and quality of teakwood needs further assessment to design economically viable management control practices.

Impact on site and long-term sustainability

Coordinated national and international efforts should be initiated through a network of permanent sample plots to assess the long-term on-site impacts of teak plantations, assessing such aspects as changes in nutrient status, soil structure, erosion, ground cover and water balance, under various clones and rotations. Factors important for maintaining the growth potential should be identified, and, where appropriate, management techniques that are more environmentally friendly should be developed and disseminated.

Products, markets and economics

Long term demand, supply and prices

Global, regional and national studies should be undertaken to assess the long-term demand, supply and prices for teak (as well as for other quality hardwoods), taking account of the segmented nature of the market and the variation in the quality and dimensions obtainable from thinnings and final fellings under short and long rotations.

Grading rules

National grading systems for teak timber need to be reviewed and necessary changes made taking into account the quality and dimensions obtainable from plantations as well as from natural forests.

Use of small dimension wood

The current and potential uses of small dimension wood from teak plantations should be assessed and further research and technology development encouraged to ensure improved conversion efficiency and value addition.

Economics of teak plantations
Economic assessment of teak plantation investment based on actual costs and benefits under different environmental conditions and management regimes should be undertaken and made widely available to provide basic information to potential investors. Such studies should clearly describe and define the inputs, and should take into account land costs and the possible variations in input costs, harvested volumes and value of outputs.

### Example of potential gain from using improved genetic material

<table>
<thead>
<tr>
<th>Year</th>
<th>Commercial harvest (cum/ha)</th>
<th>Roadside value (US$/cum)</th>
<th>Total value (US$)</th>
<th>Gain from Tree Improvement (US$) assuming 10% genetic improvement (value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 10</td>
<td>0</td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 20</td>
<td>0</td>
<td>99</td>
<td></td>
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<tr>
<td>21 30</td>
<td>50</td>
<td>109</td>
<td>5,490</td>
<td>549</td>
</tr>
<tr>
<td>31 40</td>
<td>50</td>
<td>121</td>
<td>6,070</td>
<td>607</td>
</tr>
<tr>
<td>41 50</td>
<td>50</td>
<td>134</td>
<td>6,700</td>
<td>670</td>
</tr>
<tr>
<td>50</td>
<td>350</td>
<td>970</td>
<td>339,690</td>
<td>33,969</td>
</tr>
<tr>
<td><strong>Total.</strong></td>
<td><strong>500 - i.e. 10 cum/year</strong></td>
<td><strong>357,870/ha - i.e. 7,157 US$/ha year</strong></td>
<td><strong>35,787/ha - i.e. 716 US$/ha year</strong></td>
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</tr>
</tbody>
</table>

**Carbon sequestration**

The life-cycle sequestration of carbon by teak plantations and teak wood should be quantified and compared with other plantation species and the potential of tapping CO₂ off-set funds to enhance investment in sustainable management of teak plantations should be assessed.

**Impact of certification**

Detailed studies should be undertaken on the effect of certification of plantation wood in general and teak in particular, especially in providing access to niche markets. The costs and benefits of certification should be assessed and the results disseminated among investors.

**Promotion of best practices**

National and international agencies should strive to promote best practices in the cultivation and management of teak, taking due account of the economic, social and environmental implications of different technologies. Such efforts are particularly required to ensure that small growers are able to establish and manage plantations/woodlots sustainably and to participate in certification if advantageous.

**Policies and incentives**

**Impact of policies and legislation**

The impact of current policies on investment in teak plantations should be reviewed at the national level taking into account land tenure, royalties, taxes and rules and regulations relating to the harvesting and transport of teakwood. Enabling incentives should be identified and efforts should be made to facilitate appropriate policy changes.

**Long-term credit**

Existing systems for financing investment in teak plantations should be reviewed and funding mechanisms that encourage teak as a long-term investment be developed and supported.
Institutional framework

Support mechanism for small farmers

Considering the potential role of small farmers in planting and management of teak, it is important to develop appropriate national institutional frameworks and arrangements (such as extension services) to support small-scale plantation efforts. Consideration should be given to the development of international support mechanisms to deal with common problems such as access to technology, availability of inputs, and processing and marketing of teakwood and products, possibly through ITTO.

Enabling incentives should be identified and efforts should be made to facilitate appropriate policy changes.

Public-private partnership

Partnership arrangements like co-operatives and consortia involving the public and private sectors should be developed and strengthened especially to deal with problems that cannot be dealt with effectively through individual efforts. The conservation of teak genetic resources, preferably in situ, but also ex situ, and the monitoring and control of trans-boundary pests and diseases are some of the potential areas for such collaboration. TEAKNET and TEAK 2000 should facilitate such initiatives at the regional and global levels.

Regional and global facilitation

TEAKNET

TEAKNET should be strengthened to function as an effective forum for exchanging information and bringing together the diverse interest groups dealing with teak cultivation, management, utilization and trade.

Considering the potential of TEAKNET in facilitating regional and inter-regional collaboration, the possibility of extending TEAKNET activities to other regions (Latin America and Caribbean, and Africa) should be encouraged and institutions/ countries should be assisted by TEAKNET to set up regional TEAKNET chapters to help in inter- and intra- regional collaboration.

TEAK 2000

TEAK 2000 should be developed as a mechanism to provide technical and economic guidance and advice to facilitate global interaction among growers, investors and technical experts. TEAK 2000 can serve to bring growers and investors together. A list of consultants (by region and expertise) can be compiled by TEAK 2000.

IUFRO Teak Group

Members of the IUFRO Teak Group (5.06.02 - Properties and Utilization of Plantation Grown Teak) should be encouraged to conduct in-depth studies on utilization technologies as a collaborative effort between research institutions and industries.

Teak promotion body

The feasibility of establishing a promoting body in support of global efforts to strengthen conservation and management of teak, and in particular to mobilize resources and expertise to establish teak plantations, needs to be examined.
APPENDIX – List of papers presented during the seminar

Technology and productivity issues: an introduction to the Seminar
C. TS. Nair

Global overview of teak plantations
J.B. Ball, D. Pandey and S. Hirai

Teak plantations in Bangladesh
Md. Ashraful Hoque

Site technology and productivity of teak plantations in India
K. Subramanian, A.K Mandal, N. Rambabu, Mammen Chundamannil and B. Nagarajan

Site, technology and productivity of teak plantations in Sri Lanka
N.D.R. Weerawaradne

Teak plantations in Myanmar
U Maung Maung Htwe

Current state of teak plantation technology in Thailand
Bunvong Thaiutsa

The process of establishment of teak plantations and results obtained in Vietnam
Cao Quang Nghia

Site, technology and productivity of teak: the Malaysian experience
Daniel Baskaran Krishnapillay and Abdul Razak Mohd Ali

Site, technology and productivity of teak plantations in China
Bai Jiayu and Liang Kunnan

Teak plantation productivity - Indonesia
Sadhardjo Siswamartana

Teak plantations in Brazil
Fernando Torres

Productivity of teak plantations in Cote d' Ivoire
Kadio Adjumane Aime

Experience with teak in Costa Rica
Luis Alberto Ugalde Arias and Luis Diego Perez Cordero

Domestication of teak through tree improvement
Erik D. Kjaer, Apichart Kaosa-ard and Verapong Suangtho

Gains from provenance selection
Apichart Kaosa-ard

Advances in silviculture, genetic improvement and mass propagation of teak in Sabah (Poster presentation)
Roberto Bacilieri

Prospects for propagules issued teak planting stock
Olivier Monteuuis

Vegetative reproduction of teak - the future to increased productivity
Kevin J. White and P Gavinlertvatana

Application of pest management practices in teak plantations
Chaweewan Hutacharem
Economics of teak plantations
*Mammam Chundamaninil*

Properties of teakwood as influenced by wood extractives and its importance for tree breeding *Maruli Humala Simatupang and Koichi Yamamoto*

Trends in the utilization of small dimension logs
*Suntud Sangkul*

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1 The drafting committee, consisting of 13 specialists representing different geographical regions and technical fields identified the main conclusions for subsequent discussion.

2 The appendix provides a list of all papers presented.