THOUGHTS ON THE CONSERVATION OF FOREST BIOLOGICAL DIVERSITY AND FOREST TREE AND SHRUB GENETIC RESOURCES

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PALMBERG-LERCHE, C. 2008. Thoughts on the conservation of forest biological diversity and forest tree and shrub genetic resources. This paper discusses concepts, strategies and priority setting in the conservation of forest biological diversity. It focuses on the management of forest tree and shrub genetic resources, and reviews information on values derived from their sustainable use in support of local and national development. This paper highlights the need to address gaps in information on status and trends in forest biological diversity and genetic resources using relevant indicators, and to improve available knowledge on genetic variation, phenology and breeding systems as a basis for the conservation, improvement and sustainable use of target species. It supports the notion that forest genetic resources action plans, based on country-derived information on status, trends and national priorities, should be seen in a larger regional and global perspective to help strengthen the impact of efforts in individual countries and make full use of comparative institutional strengths among countries. In order to be sustainable over time, conservation and genetic management should be incorporated in wider planning frameworks, such as national forest programmes and rural development plans. To promote and support such integration, there is an urgent need to systematically review, generate and widely publicize studies that quantify the economic, social and environmental gains obtained or obtainable from maintaining biological diversity and wisely using tree and shrub genetic resources, seen in relation to alternative land use options.

Keywords: *In situ, ex situ,* sustainable, management

PALMBERG-LERCHE, C. 2008. Pemuliharaan kepelbagaian biologi hutan serta pemuliharaan sumber-sumber genetik pokok hutan dan pokok renek: satu renungan. Kertas ini membincangkan konsep, strategi dan keutamaan dalam pemuliharaan kepelbagaian biologi hutan. Tumpuan kertas ini adalah pada pengurusan sumber genetik pokok hutan dan pokok renek. Kertas ini juga mengkaji semula pentingnya penggunaan mampan sumber genetik sebagai menyokong perkembangan tempatan dan negara. Kertas ini menekankan pentingnya menangani jurang maklumat tentang status dan trend kepelbagaian biologi hutan dan sumber genetik menggunakan penunjuk yang sesuai. Kertas ini juga menekankan pentingnya menambah maklumat yang ada tentang variasi genetik, sistem fenologi dan sistem pembiakan sebagai asas bagi pemuliharaan, kemajuan dan penggunaan mampan spesies yang disasarkan. Kertas ini menyokong tanggapan bahawa pelan tindakan sumber genetik hutan sepatutnya dilihat dengan lebih meluas iaitu dari segi perspektif global dan kawasan untuk membantu menguatkan impak tindakan negara individu serta menggunakan kekuatan bandingan antara negara dengan sepenuhnya. Pelan tindakan ini berdasarkan maklumat tentang status, trend dan keutamaan negara. Pemuliharaan dan pengurusan genetik patut digabungkan dalam rangka tindakan yang lebih luas seperti program hutan kebangsaan dan pelan pembangunan luar bandar agar dapat kekal mampan. Untuk mempromosi dan menyokong integrasi sebegini, kita perlu mengkaji semula, menghasilkan dan memberi publisiti meluas terhadap kajian tentang keuntungan ekonomi, sosial dan persekitaran yang diperoleh atau yang dapat diperoleh dengan mengekalkan kepelbagaian biologi dan penggunaan bijak sumber genetik pokok dan pokok renek dari segi pilihan penggunaan tanah.

INTRODUCTION

The conservation of forest biological diversity and the wise management of forest genetic resources help underpin local and national development. This paper briefly examines the present state of these valuable resources in the light of existing information. It recollects available strategies and methodologies for their conservation and sustainable use, and discusses the relationships

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This paper is based on an article entitled 'Forest Biological Diversity and Forest Tree and Shrub Genetic Resources: Concepts, Conservation Strategies, Priorities and Values' (Palmberg-Lerche 2007). The earlier version of the paper, published in the FAO Regional Office for Africa newsletter, Nature & Faune, was focused specifically on activities in Africa.

and complementarities between national, regional and global action in conservation and genetic management. A brief review of available information on values of diversity leads to a call for more systematic work in this field, needed to tangibly demonstrate the actual and potential economic, social and environmental gains from maintaining biological diversity and wisely using tree and shrub genetic resources.

While it is recognized that the concept of forest biological diversity includes variation and genetic resources of plant, animal, insect and microbial species (see CBD 2002; FAO 2007a), the present paper is focused on the conservation of diversity through the management and sustainable use of forest tree and shrub genetic resources.

PRESENT SITUATION

There is today a worrying loss of forest ecosystems in all tropical and sub-tropical regions caused by deforestation due to changes in land use. In addition, extensive tracts of forests and woodlands in most regions of the world are being degraded to various degrees through damage from pests, diseases, fire, atmospheric pollution, climatic fluctuations and lack of management or non-sustainable forest management practices (FAO 2006a, 2007a, 2007b).

Over the past 35 years, the number of international, regional and national institutions, mechanisms and discussion fora which are concerned with forests and forest biological diversity have greatly increased. They generally cover different aspects of work and they are discussed in some detail in a recent document by FAO on status and trends of the world's forest genetic resources (see Chapter 5 and Annex 1 of FAO 2007a).

Increasing data are becoming available on status and trends of the forests of the world (FAO 2006a, 2007b). On the other hand, information on changes in forest area and qualitative variables commonly recorded in forest inventories today cannot be directly used to estimate changes in variation at the level of species, provenances, populations and genes. By and large, however, forest loss can be expected to have negative effects on diversity. Reviewing general data on forest resources is thus an important starting point for assessing and monitoring forest biological diversity and efficiently managing forest genetic resources. Trends in selected variables related to biological diversity in tropical forest ecosystems, as reported in the Global Forest Resources Assessment (FAO 2006a), are shown in Appendix 1.

Information is gradually also becoming available on forest biological diversity, and status, trends and priorities in the management of forest genetic resources (see Appendix 2). However, such information is still incomplete and patchy. Assessing and monitoring diversity at the different levels at which it occurs is, furthermore, hampered by the lack of agreed-upon indicators to identify changes and trends (see Chapter 9 of FAO 2007a for a discussion of relevant indicators and references to related information).

STRATEGIES AND METHODOLOGIES

Neither forest ecosystems nor the genetic resources found in them are static. Action taken to sustain them must not be aimed at freezing a given state, as this would imply an arbitrary fixation of dynamically evolving, living systems (see Eriksson & Namkoong 1993).

Conservation of forest biological diversity and forest genetic resources implies varying intensities of human intervention, including non-intervention. In order to be sustainable over time, efforts to maintain or enhance diversity require that forests and woodlands be managed to meet stated productive, protective, social and environmental goals in a balanced manner, and that the resources be wisely utilized in support of local and national development, including poverty alleviation and food security, economic and social advancement and the safeguarding of cultural and spiritual values.

Biological diversity includes variation at landscape, ecosystem, species, population, individual, genetic and molecular levels of biotic organization (IPGRI *et al.* 2004a, FAO 2007a). As the various levels at which diversity occurs are inter-related, a comprehensive approach to conservation is necessary. At the same time it is necessary to specify clearly the level or levels targeted by specific management action, as it is possible to conserve an ecosystem and still lose given species, and to conserve a species and lose genetically distinct populations, genes or valuable gene complexes. Goals for conservation and the management of forest genetic resources ought to be made explicit and agreed as broadly as possible at the beginning of any conservation

effort ('of what, for what, for whom, how, with what time-scale and with what institutional and financial resources?'). Since economic, social and environmental priorities continually shift, conservation and management objectives will however need to be kept flexible to address new needs, and will need to incorporate new knowledge and understanding as they become available.

Decisions regarding conservation strategies and methodologies will depend on the status and dynamics of genetic variation of target species and their biological characteristics. Other considerations which will affect related decisions include the importance, uniqueness and present use of these species, the degree of knowledge on their silviculture and management, perceived threats and, quite decisively, institutional possibilities in countries concerned, including human resources, infrastructure and availability of short-, medium- and long-term funding.

In situ, on-site, conservation and *ex situ* conservation as seed, pollen or tissue and in special plantations or field collections should be used to complement each other in forest genetic resource programmes, and both strategies should be given due attention. The maintenance of an appropriate combination of genetic resource areas in a number of different locations, under diverse environmental and silvicultural conditions and varying intensities of management, is however the most efficient way to conserve genetic variation at its different levels. In practice, this implies (i) the conservation of forest biological diversity and genetic resources in protected areas, (ii) the incorporation of genetic considerations in forest resource management for productive or protective purposes (including natural forests and forest plantation establishment and management) and (iii) the incorporation of such considerations in tree improvement and breeding strategies (Palmberg-Lerche 1999, 2002a).

To ensure sustainability and long-term success, conservation concerns should be integrated in broader local and national development plans. Such plans might include national forest programmes and poverty reduction strategies, which promote harmonization of action between economic sectors and co-operation among national agencies dealing with these. Integration should be assured at both policy-making and implementation levels. Appropriate links should also be established with efforts by countries to meet the Millennium Development Goals (MDGs), notably MDG 1 ('Eradicate Extreme Poverty and Hunger') and MDG 7 ('Ensure Environmental Sustainability'), to which forestry can make substantial contributions (FAO 2006b, Roe & Bond 2007).

Wider policy and action frameworks at eco-regional, regional and global levels will strengthen the impact of genetic management in individual countries, and can help draw attention to issues of regional and global concern which might inadvertently be overlooked or neglected in national forest genetic resources strategies. Regional collaboration will also help avoid wasteful duplication of effort by making full use of institutional strengths and comparative advantages among countries (FAO 2001, Palmberg-Lerche 2002a , FAO 2007a).

Conservation must be accompanied by regular monitoring, using relevant indicators, to ensure that progress is being achieved in reaching stated objectives. Management action must be adjusted, should the need to do so arise (see FAO 2002a, 2002b for information on genetic indicators). Information on expected and realized benefits and returns should be analyzed and widely disseminated to all stakeholder groups.

Priority-setting

Estimates of the total number of tree species in the world vary from 80 000 to 100 000. It is clear that there is a need for priority setting among the many species and ecosystems which may qualify for action.

The general aim of priority setting is to compare the consequences and trade-offs of a number of alternative choices and actions. It implies that some ecosystems, species or genetic resources will be given lower priority than others. This is not to say that they have no conservation value, rather, that in relation to agreed-upon, common local, national, regional or international goals in any one programme, some species or actions are not as urgent as others (Williams 1999, FAO 2007a).

Relative priorities within any one country will be determined by balancing socio-economic, environmental and cultural values assessed in the light of susceptibility or likelihood of loss or

degradation of ecosystems and genetic resources of species targeted for action. At the regional and global levels, priority-setting will, in addition, take into account common interests and commonality of priority species and activities. Priority setting is complicated greatly by the lack of even basic information on the variation, variation patterns and potentialities of many (or most) forest tree species (FAO 2007a).

Forest management interventions and non-intervention, which are based on local and national priorities, will have varying effects on different social and economic sectors. To ensure broadly-based support and sustainability of action, genuine efforts are needed to meet the needs and aspirations of the fullest possible range of interested parties. This underlines the necessity for wide stakeholder participation, in order to agree on compromises. What is valued in biological diversity, how it can be managed and for whom are critical issues.

When evaluations of priorities among stakeholders are similar, concerted action is possible, but when dissimilar, independent but co-ordinated action is more likely to succeed. There will frequently be substantial differences in perceived values and priorities between sectors of the economy and among governmental and non-governmental organizations and other groups active in forest biological diversity conservation, genetic management and related development programmes. In such cases, it will be necessary to form coalitions for action and harmonize these under a coherent framework, at appropriate level.

VALUES OF DIVERSITY

Many values are derived from forest ecosystems as well as from their component parts. They include the provision of goods and services and the maintenance of environmental and life-support values. These latter values, such as soil and water protection, carbon sequestration, the conservation of biological diversity and recreation are typically associated with the ecosystem and forest population levels. Goods (wood and non-wood products) harvested from forests are usually provided at the species or forest population levels, while evolution and adaptation to medium- and long-term environmental change, and breeding to meet present-day and future needs, are mainly dependent on gene-level and molecular variation.

There is no single measure for the value of biological diversity or genetic resources. Measures are only possible for particular aspects, seen in relation to specific goals (see Williams 1999, Palmberg-Lerche 2002a, FAO 2007a).

A search for information related to 'value of biological diversity', carried out in February 2008 using a leading Internet Search Engine, provided 1.1 million hits in 0.42 seconds and a search for 'value of forest biological diversity', provided 211 000 hits in 0.35 seconds. In spite of this, information on the actual values of diversity seems to be scarce. At closer look, in relation to the latter search, the majority of the studies and papers which were listed concerned the value of forest resources, or forest (vegetation) cover, rather than the value of diversity. A number of other studies reviewed the value of given species as food, fodder and medicine. However, they seldom dealt with the value of using or enhancing genetic variation found within these species. Others, again, focused on the value of useful chemical compounds in given species, with little or no regard to analysing the possible benefits of maintaining variation in such compounds among populations or individuals. A systematic review of available information on values of diversity and genetic variation is urgently called for.

In managing natural forests and woodlands or establishing forest plantations, foresters make use of species and intra-specific genetic variation found in natural tree populations, which buffer them against environmental heterogeneity, changes in the environment and variations in end use requirements over time. Intra-specific variation between geographically distinct forest tree populations is referred to in forestry as 'provenance variation'. Most documented information on the social and economic gains, which can be achieved by maintaining, wisely utilizing and enhancing genetic variation in forest trees, is related to the use of provenance variation in forest plantation establishment and tree planting (see Appendix 3).

Another area in which studies have confirmed that high socio-economic returns can be achieved by the exploration and use of intra-specific variation, is tree breeding. Yet, surprisingly, scientifically valid, genetic information which is needed to advance in improvement and breeding

is still today available for only some 50 forest tree species, and only some 500 species have been systematically tested for their present-day utility (Anonymous 1991, FAO 2007a). Some case studies on gains achieved in tree breeding programmes, based on the use of natural variation between and within provenances, are provided in Evans (1999); FAO (2001, 2002c); IPGRI *et al.* (2001, 2004a, 2004b); Libby and Palmberg-Lerche (2002); and Palmberg-Lerche (1999, 2002a, 2002b).

To ensure that conservation concerns receive due attention in all stages of planning and implementation and that such concerns are integrated in broader local and national development programmes, there is an urgent need to further review and widely publicize studies that quantify the economic, social and environmental values obtained or obtainable from maintaining biological diversity and wisely using tree and shrub genetic resources, seen in relation to alternative land use options and specific conservation and forest management goals.

CONCLUSIONS

Genetic variation in trees and shrubs underpins the continued health and vitality of forest ecosystems, buffers forests against environmental fluctuations and changes, and helps ensure that new and emerging needs of human populations can be adequately met now and in the future. The conservation of forest biological diversity and the wise management of forest genetic resources are not limiting factors to development but a precondition for lasting well-being.

In order to promote and support integration of conservation and genetic management in wider national planning frameworks, the advantages and gains of conservation and the costs of mismanagement or neglect must be convincingly demonstrated.

Vigorous efforts are needed to expand existing forestry and genetic resources information to support action and priority setting, both in regard to country and species coverage. Such priority setting will help ensure that programmes aimed at conservation and genetic management are relevant and adequately focused, and that they make optimal use of institutional and financial resources at local, national, regional and global levels. The development and application of reliable indicators to monitor changes in status of diversity and genetic variation over time is also imperative, as indicators will help verify the effects of action taken and allow dynamic adaptation of programmes to meet new and changing needs.

In addition to the need to clarify status and dynamics of genetic variation, there is an urgent need to gain added knowledge of phenology and breeding systems in forest tree species as a basis for their genetic management, including conservation, improvement and sustainable use.

Strategies and methodologies for the conservation of forest biological diversity and the management of forest genetic resources will vary according to biological, social and economic environments, institutional realities, and local and national needs and priorities. While the existing information base is weak and needs to be improved, there are today no fundamental scientific and technical obstacles to meeting conservation objectives in forests and woodlands managed or established for the production of timber, non-wood products, recreation, and the protection of soil, water and other social and environmental values. Sadly, however, non-compliance with sound conservation and forest management practices and failure to incorporate genetic considerations in forest establishment and plantation management, are still common causes of loss of diversity and unnecessary damage to site, vegetation and regeneration in all kinds of forests.

The above technical shortcomings are frequently exacerbated by a lack of adequate national policy and institutional frameworks under which alternative land use options and operational forest and land management choices, fair to all stakeholders, can be considered and efficiently implemented. Harmonization of action between economic sectors and co-operation among agencies are today a pressing need.

Finally, while progress in conservation is dependent on action of individual countries and national institutes, efforts can only be fully effective if they are related to larger eco-regional, regional and global forest genetic resources frameworks which help ensure that important issues are not inadvertently overlooked, that wasteful overlap is avoided, and that comparative institutional advantages, at all levels, are drawn upon to streamline action.

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Appendix 1 Trends in selected variables related to biological diversity in tropical forest ecosystems

Extracted from FAO (2006a), Chapter 8, "Progress towards sustainable forest management"

AFRICA. The area of primary forest in Africa decreased by some 270 000 ha annually during 1990–2005. However, information for this variable was based on 46 countries that together accounted for only 67% of the forest area, with information missing from most of the countries in the Congo Basin (which represents the second largest area of tropical primary forest after the Amazon Basin). Some of this decrease was caused by deforestation, some by alteration of forests through selective logging and other human interventions. This 'altered' forest area was subsequently classified as 'modified natural forest'. On a positive note, there has been an increase in the area of forest designated primarily for conservation of biological diversity of close to 3 million ha since 1990. General Conclusions. Progress towards sustainable forest management in Africa appears to have been limited during the last 15 years. There are some indications that the net loss of forest area has slowed down and that the area of forest designated for conservation of biological diversity has increased slightly. However, the continued, rapid loss of forest area (the largest of any region during the 15-year period under review) is particularly disconcerting.

ASIA. The area of primary forest decreased at the alarming rate of 1.5 million ha per year during the last 15 years, entirely explained by large losses in the sub-region of South and Southeast Asia, particularly in Indonesia. The cause of the decrease was not only deforestation but also alteration of forests through selective logging and other human interventions, which resulted in a subsequent classification of such forests as 'modified natural forest'. About 13% of the forest area is currently designated primarily for conservation of biological diversity, representing an average annual increase of some 850 000 ha or about 1.3% since 1990. General Conclusions. Forest area was almost the same in 2005 as in 1990 (572 million ha as compared to 574 ha, a decrease of 0.03 % per year). Forest loss was compensated by large-scale afforestation efforts during the last 7–8 years, particularly in China. Forest health deteriorated, but forest fires, pests and diseases were still affecting a relatively small proportion of the total forest area in Asia (2.2, 2.6 and 2.4% respectively). The rapid decrease in area of primary forest is cause for concern, while the increase in area designated for conservation of biological diversity and for protective functions is commendable. In short, there has been mixed progress over the last 15

EUROPE. Four percent of the forest area is currently designated primarily for conservation of biological diversity. If the Russian Federation is excluded, the share is about 12%. There was a large increase in this area since 1990 (1.2 million ha per year). The figures on primary forest included the Russian Federation, in which large changes were primarily owing to the introduction of a new classification system. Excluding the Russian Federation, there was still a slight increase, which is explained by the fact that new areas of natural forest have been set aside and protected from human intervention. With time, these areas evolve into forests in which there are no clearly visible indications of human activity and ecological processes are not significantly disturbed by man, which is the definition of primary forests used in FRA 2005. General Conclusions. Data availability was good and the status of forest resources in Europe was essentially stable, although forests suffered from occasional storms. The severe storms of 1999 were the main reason for the negative trend in the health and vitality of forests. The focus of forest management in Europe has clearly shifted away from productive functions towards conservation of biological diversity, protection and multiple uses.

NORTH AND CENTRAL AMERICA. Total forest area decreased, but the change rates were below 0.2% per year (N.B. however that in this region the estimate excluded productive forest plantations).The area of forest designated for conservation of biological diversity increased by 712 000 ha per year since 1990, or more than 10 million ha in total. General Conclusions. Progress towards sustainable forest management was generally positive during the period 1990–2005, with none of the annual rates of negative trends being more than 0.20%, with the exception of the forest area adversely affected by insects, diseases and other disturbances. There was, however, considerable variation among sub-regions.

OCEANIA. There was a slight increase in area of primary forest. Information availability was insufficient on area of forest designated for biological diversity conservation (1990 data were missing for Australia). Total forest area, excluding area of productive forest plantations, decreased slightly, following the trend for forest area as a whole. General Conclusions. Information availability for Oceania was generally very poor. Data were insufficient for determining regional trends for two-thirds of the variables included in FRA 2005. Thus it is difficult to assess progress towards sustainable forest management.

SOUTH AMERICA. Primary forests accounted for 77% of the total forest area in the region but they continued to decrease rapidly. The net loss of primary forest increased from 3.0 million ha per year in the period 1990-2000 to almost 3.9 million ha in the period 2000-2005. Apart from deforestation, the decrease was caused by alteration of forests through selective logging and other human interventions, which resulted in a subsequent classification of such forests as "modified natural forests". The area of forest designated primarily for conservation of biological diversity increased by about 3.3 million ha per year in the last 15 years, or a total of 50 million ha, equivalent in size to the area of primary forest lost during this period. General Conclusions. Progress towards sustainable forest management was mixed. The increasing trend in the area of net forest loss is a cause for concern, as is the rate of loss of primary forest. Yet there were also positive signs in the increased areas of forest designated for conservation of biological diversity and for social services.

Appendix 2 Sources of information on forest biological diversity and forest tree and shrub genetic resources

The purpose of the below notes is to highlight some relevant sources of information on forest biological diversity and genetic resources and to provide corresponding links, for easy reference. For a more comprehensive overview, see FAO (2007a). Information sources marked with an asterisk (*), are available in English, French, Spanish, at times also Arabic and Chinese.

1. FOREST BIOLOGICAL DIVERSITY

* The Convention on Biological Diversity (CBD)*: http://www.cbd.int/default.shtml;
* The FAO Inter-Departmental Group on Biological Diversity in Food and Agriculture*: http://www.fao.org/biodiversity/ecosystems/bio-forests/en/

2. FOREST GENETIC RESOURCES

The FAO Forest Genetic Resources Homepages host information on various aspects of the management of forest genetic resources*, see: http://www.fao.org/forestry/site/fgr/en/. This includes, i.a.:

* Information generated within the framework of the Panel of Experts on Forest Gene Resources*: http://www.fao.org/forestry/site/genepanel/en/. The work of the Panel includes regularly up-dated lists of species and provenances of high global, regional and/or national priority for genetic management: http://www.fao.org/docrep/007/j4027e/j4027e00.htm. It also includes regional updates on status, trends, priorities and needs, see Baskaran *et al.* 2002: http://www.fao.org/DOCREP/005/AC646E/AC646E00.HTM; and Baskaran *et al.* 2004: http://www.fao.org/forestry/webview/media?mediaId=12131&langId=1
* National and regional level information prepared within the framework of country-driven regional, sub-regional and eco-regional workshops on forest genetic resources supported by FAO and international partners. Related information has been published as FAO Forest Genetic Resources Working Papers, see: http://www.fao.org/forestry/site/41119/en/ (click on the heading "Working Papers" on the left-side menu). Summarized information is available also in Section 10 of FAO (2007a).
* Information generated within the framework of some regional forest genetic resources networks such as those listed in Tables 1 and 2.
* The FAO Forestry Database on Forest Genetic Resources, REFORGEN: http://www.fao.org/forestry/reforgen/. For a brief description of REFORGEN and other databases relevant to work on forest genetic resources, see Section 11 of FAO (2007a).

3. GENERAL INFORMATION ON FORESTS AND FOREST ECOSYSTEMS

Sources of regularly up-dated information include the Global Forest Resources Assessments*: http://www.fao.org/forestry/site/fra/en/ and http://www.fao.org/forestry/site/data/en/; and national forest programmes*: http://www.nfp-facility.org/home/en/.

In addition, general information of relevance can be found at the Homepages of i.a. the following:

* Bioversity International (formerly known as IPGRI): http://www.bioversityinternational.org. Bioversity International is, "dedicated to research on the conservation and use of agricultural biodiversity". A number of Bioversity-coordinated networks which deal with forest genetic resources are listed in Table 1.
* The World Agroforestry Center, ICRAF: http://www.worldagroforestrycentre.org/. ICRAF deals with research on trees grown in agroforestry systems to, "generate knowledge on the complex role of trees in livelihoods and the environment".
* The Center for International Forestry Research, CIFOR: http://www.cifor.cgiar.org/. CIFOR focuses on research to underpin, "conserving forests and improving the livelihoods of people in the tropics".
* The International Tropical Timber Organization, ITTO: http://www.itto.or.jp/live/index.jsp.ITTO. "promotes the conservation and sustainable management, use and trade of tropical forest resources".

Appendix 2—Table 1 Examples of regional collaborative networks in the management of forest genetic resources

Region	Network	Links
Africa	Sub-Saharan African Forest Genetic Resources Programme, SAFORGEN	http://www.bioversityinternational.org/Information_Sources/Networks/saforgen/index.asp
Americas	International Cooperative for Tree Conservation and Domestication, CAMCORE (earlier know as the Central America and Mexico Coniferous Resources Cooperative)	http://www.camcore.org/
	FAO North American Forest Commission Working Party on Forest Genetic Resources	http://www.fs.fed.us/global/nafc/genetics/aboutus.htm
	Latin America Forest Genetic Resources Programme, LAFORGEN	http://www.bioversityinternational.org/Information_Sources/Networks/laforgen/index.asp
Asia-Pacific	Asia Pacific Forest Genetic Resources Programme, APFORGEN	http://www.apforgen.org/
	ASEAN Regional Biodiversity Conservation Programme, of the ASEAN Regional Centre for Biodiversity Conservation	http://www.arcbc.org.ph/about_ARCBC.htm
	Central Asia and Trans-Caucasus Network on Plant Genetic Resources, CATCN-PGR; and its Working Group on Forest Trees	http://www.bioversityinternational.org/Information_Sources/Networks/index.asp
	South Pacific Regional Initiative on Forest Genetic Resources, SPRIG	http://www.fao.org/docrep/008/x9662e/X9662E11.htm
Europe	European Forest Genetic Resources Programme, EUFORGEN	http://www.bioversityinternational.org/networks/euforgen/
General	The International Union of Forest Research Organizations, IUFRO, promotes cooperation in forest-related research through networking of research institutions and scientists. See especially: * Division 2 (Physiology and Genetics); * Working Party 2.04.01 (Population, ecological and conservation genetics); * Task Force on Endangered Species and Nature Conservation	http://www.iufro.org/who-is-who/
	Regional Chapters of IUFRO include the Asia Pacific Association of Forestry Research Institutions, APAFRI.; and the North-East Asian Forest Forum, NEAFF. Collaborative networks are active also in other regions.	http://www.apafri.org/ http://www.iufro.org/discover/regions/northeast-asia/ http://www.iufro.org/discover/regions/

Appendix 2—Table 2 Examples of species-specific networks and networks covering priority genera

Name of project or network	Geographical coverage	Species or genera	Links
Genetic Resources of Arid and Semi-Arid Zone Arboreal Species for the Improvement of Rural Living	Africa, Asia, Latin America, Near East (arid and semi-arid zones)	*Acacia* spp., *Prosopis* spp.	http://www.sl.life.ku.dk/dfsc/pdf/Aridzone%20trials/index.html; and http://www.fao.org/DOCREP/006/Q5987E/Q5987E17.htm
International Neem Network	Africa, Asia-Pacific, Latin America, Near East (tropics)	*Azadirachta indica*	http://www.fao.org/forestry/50364/en
International Network for Leucaena Research and Development, LEUCNET	Africa, Asia-Pacific, Latin America, Near East, North America (tropics, sub-tropics)	*Leucaena leucocephala, Leucaena* spp.	http://www.sl.ku.dk/dfsc/Extensionstudy/Forest%20Reproductive%20Material%20website/FRM-2810.htm
Network on the conservation, management, utilization and trade of teak, TEAKNET	Africa, Asia-Pacific, Latin America (seasonal tropics)	*Tectona grandis*	http://www20.brinkster.com/teaknet/
International Network for Bamboo and Rattan, INBAR	Africa, Asia, Latin America, Near East, [North America] (tropical, sub-tropical, temperate zones)	Bamboo and rattan species	http://www.inbar.int/
International Centre for Research and Training on Seabuckthorn, ICRTS/ International Seabuckthorn Association, ISA	Asia, Europe, Latin America, North America (cold-temperate zones)	*Hippophae rhamnoides, Hippophae* spp.	http://www.icrts.org/
International Poplar Commission, IPC and its Working Parties	Africa, Asia, Australia & New Zealand, Europe, Latin America, Near East, North America, (temperate, sub-tropical zones)	*Populus* spp., *Salix* spp.	http://www.fao.org/forestry/site/34797/en/

Appendix 3 Value of forest genetic resources: provenance variation

Forest tree species are among the genetically most variable organisms on earth. They are generally characterized by long life cycles and wide natural distribution areas. The span of time over which external changes may assert selective pressure on forest tree species and populations varies from days to decades, and the spatial scale varies from local to regional. In response, trees have developed complex mechanisms to maintain high intra-specific (within species) diversity, which allows them to evolve and adapt to changing conditions.

The manifested, high level of differentiation in adaptive genetic traits among and within forest populations has underpinned the development of forest genetic studies and tree breeding programmes over the past 70 years. In addition to high levels of intra-specific variation, tree species have frequently developed genetically diversified local populations of actual or potential value both for adaptation to natural environmental change (including climatic fluctuations and emerging threats from pests and diseases), and for selection and breeding by man. Such inter-population variation, referred to in forestry as provenance variation, may at times be as significant and practically important as that between different tree species, and must consequently be explored and used as a basic component in forest plantation and tree breeding programmes. Genetically diversified local populations which may possess valuable attributes, or reproductive materials collected from them, must also be included in genetic conservation programmes, with due regard to safeguarding such gene pools from hybridization with introduced provenances (Palmberg-Lerche 2001, 2002b).

The practical importance of systematic testing of provenance variation has been convincingly demonstrated in economic terms (see information in e.g. Evans 1999; FAO 2002c, Libby & Palmberg-Lerche 2002; Palmberg-Lerche 2001, 2002b). The international provenance trials of Eucalyptus camaldulensis, coordinated by FAO in the 1960s, were among the first of a number of such trials. Experiments were established on 32 sites in 18 countries, and they showed that the potential gains in growth and yield which could be achieved by selection of the best-adapted provenances for prevailing environmental conditions, amounted to several hundred percent, with differences in growth between provenances planted at any one experimental site ranging from 300% in northern Nigeria, to 800% in Israel (Lacaze 1978a, 1978b; Palmberg-Lerche 2002b). Spectacular provenance differences were also found in dry-zone Acacia and Prosopis species and provenances in a series of FAO coordinated trials in the 1980s and 1990s (Palmberg 1983, Palmberg-Lerche 2002b).

Following species and provenance selection in Acacia, Casuarina and Eucalyptus species and the introduction of better silvicultural methods, yields in forest plantations in China more than doubled in the 1980s and 1990s, and rotation times decreased by 30%. The mean internal rate of return in the plantation schemes reviewed, using a 5% discount rate, was 35%. In the case of Acacia mangium, the productivity of large-scale plantations in Indonesia was doubled by the use of better adapted provenances, as compared to yields obtained by using the relatively poor quality seed previously used. These stands were also of better quality in regard to stem straightness and branching (McKenney 1998).

An early, documented programme, which focused on increasing gum yield in Pinus elliottii in South-Eastern USA, combined selection at provenance and individual tree levels, breeding, and the development of improved silvicultural and tapping methods. The programme was initiated as early as 1941 to meet increasing needs of the naval stores industry, and was wound down in the early 1970s due to a decrease in the demand for natural gums in the USA. By that time, however, increases in gum yields of 50-106% had been achieved, as well as increased yields of wood, tall oil (rosin) and turpentine. There were also appreciable gains in stem straightness and crown form, which had been included among the criteria when selecting the founder provenances, plus trees and clones included in the programme (Squillace *et al.* 1972). This project which started 67 years ago, can provide many lessons on various aspects of tree breeding programmes and related considerations, and should be considered a classic.