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THE USE AND EXCHANGE OF FOREST GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Submission by the Food and Agriculture Organization of the United Nations (FAO)

Note by the Executive Secretary

1. Further to the request of the Commission on Genetic Resources for Food and Agriculture, the Executive Secretary is pleased to circulate herewith, for the information of participants in the ninth meeting of the Ad Hoc Open-ended Working Group on Access and Benefit-sharing, a study entitled "The use and exchange of forest genetic resources for food and agriculture" prepared at the request of the Secretariat of the Commission on Genetic Resources for Food and Agriculture and considered at its twelfth regular session.

2. The paper is being circulated in the form and language in which it was received by the Secretariat.

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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

THE USE AND EXCHANGE OF FOREST GENETIC RESOURCES FOR FOOD AND AGRICULTURE

by

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This document was commissioned by the Secretariat of the Commission on Genetic Resources for Food and Agriculture to Bioversity International, in preparation of the Commission's cross sectoral theme, *Consideration of policies and arrangements for access and benefit-sharing for genetic resources for food and agriculture,* at its Twelfth Regular Session.

The content of this document is entirely the responsibility of the authors, and does not necessarily represent the views of the FAO, or its Members.

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ABOUT THIS PUBLICATION

The Commission on Genetic Resources for Food and Agriculture (the Commission), at its Tenth Regular Session, recommended that the Food and Agriculture Organization of the United Nations (FAO) and the Commission contribute to further work on access and benefit-sharing, in order to ensure that it moves in a direction supportive of the special needs of the agricultural sector, in regard to all components of biological diversity of interest to food and agriculture.

At its Eleventh Regular Session, the Commission agreed on the importance of considering access and benefit-sharing in relation to all components of biodiversity for food and agriculture, and decided that work in this field should be an early task within its Multi-Year Programme of Work (MYPOW). Accordingly, the Commission decided to consider arrangements and policies for access and benefit-sharing for genetic resources for food and agriculture at its Twelfth Regular Session (19-23 October 2009). To facilitate discussions and debate on access and benefit-sharing for genetic resources for food and agriculture at the Twelfth Regular Session, the Secretariat of the Commission has commissioned several background study papers on use and exchange patterns of genetic resources in the different sectors of food and agriculture. The studies provide an overview of past, current and possible future use and exchange patterns, as well as a description of terms and modalities for use and exchange of animal, aquatic, forest, micro-organism genetic resources; and of biological control agents. The current Background Study Paper deals with forest genetic resources for food and agriculture. Cross-sectoral studies have been commissioned to analyse use and exchange patterns in light of climate change and to review the extent to which policies and arrangements for access and benefit-sharing take into consideration the use and exchange of genetic resources for food and agriculture in particular.

The broad ranges of studies are intended to provide insight, necessary to maintain, establish and advance policies and arrangements for access and benefit-sharing for biodiversity for food and agriculture. The studies may also contribute to the negotiations of an International Regime on Access and Benefit-sharing in the Ad Hoc Open-ended Working Group on Access and Benefit-sharing under the Convention on Biological Diversity.

EXECUTIVE SUMMARY

This report focuses on forest genetic resources, i.e. the genetic variation between and within tree species, and more specifically, on the use and movement of forest reproductive material – or germplasm (that is, seeds, cuttings or other propagating parts of a tree) – needed for regenerating natural forests and establishing plantations and agroforests. Planted forest area has steadily increased during the past decades and this trend that is likely to continue. The Food and Agriculture Organization of the United Nations (FAO) estimates that the total area of planted forest has increased from 209 million ha in 1990 to 271 million ha in 2005, equivalent to approximately 7 percent of the total global forest area. Furthermore, "trees outside forests" (e.g. open woodlands and agroforestry systems) also provide tree products and services that support the livelihoods of more than one billion smallholders.

Seeds of tree species, the most common type of forest reproductive material, are obtained from a variety of sources, including wild stands, selected seed stands, seed orchards, research trials, plantations and even individual trees on farms, depending on tree species and countries. Selected, improved or tested material is available for relatively few tree species. Only a small number (less than 140) of the world's 50,000 or so tree species are being used in commercial forestry and current tree breeding efforts focus on still fewer taxa. The gene pools of many tree species, even in breeding programmes, are still semi-wild, while only a few tree species have been domesticated at a level similar to agricultural crops.

Movement of tree germplasm has a long history, but comprehensive data on either past or current introductions are not available. Furthermore, a global assessment of forest genetic resources has not yet been conducted; however, a process has been initiated by FAO to prepare the State of the World's Forest Genetic Resources report by 2013. The present report summarizes available information on the movement of tree germplasm, focusing on selected groups of tree species important for human well-being and which provide both wood and non-wood products. These broad groups include 1) fast-growing plantation tree species, 2) tropical hardwoods, 3) agroforestry tree species, and 4) temperate and boreal tree species.

Tree seed crops have a high year-to-year variation, and the need to maintain seed storage capacity and maximise harvesting efforts during good seed crop years therefore requires considerable resources. In the case of agroforestry tree species, the lack of adequate smallholder germplasm delivery systems exhibits a major limitation for tree planting efforts. Centralised models of delivery, such as those based around National Tree Seed Centres (NTSCs), have been appropriate for supplying the plantation industry but have delivered less than 10 percent of the smallholder demand for tree seedlings and seed. This is due to the fact that small-scale farmers are often widely dispersed and require only small volumes of particular tree species, making it expensive to reach them. More decentralised models of tree germplasm delivery, supported by many donors and carried out by non-governmental organizations (NGOs), do not appear to have improved the general situation for small-scale farmers, due to a range of factors including the restricted timescale of projects, the lack of attention to the promotion of high quality material, and insufficient technical knowledge in handling tree germplasm.

Movement of forest reproductive material has brought considerable benefits to many countries and to small-scale farmers. Agroforestry tree species, for example, are presently used, on average, in 21 countries beyond their native ranges. Current seed production is sometimes unable to meet local, national or international demand. International field trials of different provenances of tree species have made valuable information available and also contributed to the increasing demand for seeds. These efforts need to be continued and strengthened through international cooperation. In addition, an increasing demand for forest reproductive material of native, non-traditional commercial tree species exists, as recent research efforts have demonstrated their potential to provide high quality wood and other products relatively fast, creating opportunities for smallholders, in particular.

It is often feared that the movement of forest reproductive material may contribute to the spreading of pests and diseases, or that introduced tree species will become invasive. In many cases, however, these concerns are over-emphasized. Preventive measures to control these risks are necessary, but they need to be implemented in a manner which does not create a barrier for the use and movement of forest reproductive material. In the face of climate change, the movement of forest reproductive material will become even more important as it provides opportunities to facilitate the adaptation of forests and to maintain productivity of forests and tree-based farming systems. Furthermore, the gene pools of important tree species are rather narrow in certain countries and regions. In these instances, there is a need to broaden the gene pools to maintain the adaptability, productivity and disease resistance of the tree species.

Increasing difficulties exist (e.g. high costs, lack of access and inappropriate implementation of phytosanitary rules) in obtaining and moving forest reproductive material, especially for research purposes. Phytosanitary requirements, in particular, differ from country to country and among types of material moved. Many such rules and requirements are clearly necessary and reasonable, yet in some cases these regulations may be arbitrary and unnecessarily restrictive, creating serious limitations to further exploration, assessment and improvement efforts.

A number of international agreements that cover aspects related to the conservation and use of forest genetic resources have been established; however no sector-specific initiatives on access and benefit-sharing issues related to tree germplasm currently exist in the forest sector. Furthermore, forest genetic resources are not included in the Global Plan of Action for the Conservation and Use of Plant Genetic Resources for Food and Agriculture or in the International Treaty on Plant Genetic Resources for Food and Agriculture. The movement of forest reproductive material is sometimes based on various bilateral agreements, including Material Transfer Agreements (MTAs) and Memorandums of Understanding (MoUs), but no standard MTA is used [excluding the World Agroforestry Centre's (ICRAF's) collection of tree germplasm as part of the Consultative Group on International Agricultural Research (CGIAR) system]. In many cases, the movement of the material is poorly documented.

LIST OF ACRONYMS

ABS	Access and Benefit-sharing
AFTD	Agroforestree Database
ATSC	Australian Tree Seed Centre
AQIS	Australian Quarantine Inspection Service
BANSEFOR	Tree Seed Bank
BLSF	Latin American Tree Seed Bank
CATIE	Tropical Agricultural Research and Higher Education Center
CBD	Convention on Biological Diversity
CGIAR	Consultative Group on International Agricultural Research
CITES	Convention on International Trade in Endangered Species
CMG & BSF	Center for Genetic Improvement and & Tree Seed Bank
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DANIDA	Danish International Development Agency
ESNACIFOR	National School of Forest Sciences
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FGR	Forest Genetic Resources
FRM	Forest Reproductive Material
FRC	Forest Research Centre
GRU	Genetic Resources Unit
ICRAF	World Agroforestry Centre
IFF	Intergovernmental Forum on Forests
IPF	Intergovernmental Panel on Forests
INAFOR	National Forest Institute
ITGRFA	International Treaty on Plant Genetic Resources for Food and Agriculture
IUFRO	International Union of Forest Research Organizations
KLF	Komatiland Forests

KFSC	Kenya Forestry Seed Centre
KEPHIS	Kenya Plant Health Inspectorate Service
MCPFE	Ministerial Conferences on the Protection of Forests in Europe
MoU	Memorandum of Understanding
MTA	Material Transfer Agreement
NGO	Non-governmental Organization
NLBI	Non-legally-binding
NTSCs	National Tree Seed Centres
OECD	Organisation for Economic Co-operation and Development
ONS	National Office of Seeds
PNG	Papua New Guinea
PROFORCA	Productos Forestales de Oriente C.A.
PROSEFOR	(Regional) Project on Tree seeds
REDD	Reduction of Emissions from Deforestation and Degradation
SETRO	Tropical Seeds Company
SNGF	Silo National des Graines Forestières
TSSD	Tree Seed Suppliers Directory
UNCED	United Nations Conference on Environment and Development
UNFF	United Nations Forum on Forests
USDA	United States Department of Agriculture

CHAPTER I: Scope of the study

1.1. Genetic resources covered

This study deals with forest genetic resources, i.e. the genetic variation between and within tree species, and the economic, scientific or societal value (current and future) of this diversity (FAO 1989). Despite ongoing deforestation and forest fragmentation, the world's forests still harbour significant genetic resources. In 2005, global forest cover accounted for 3.9 billion ha and the annual deforestation rate between 2000 and 2005 was 7.3 million ha (0.18 percent) (FAO 2006a). Planted forest area has steadily increased during the past decades; a trend that is likely to continue. The Food and Agriculture Organization of the United Nations (FAO) estimates the total area of planted forest increased from 209 million ha in 1990 to 271 million ha in 2005 (FAO 2006b), equivalent to approximately 7 percent of the total global forest cover. Most planted forests are located in Asia (49 percent) and Europe (29 percent). Tree planting activities in Asia have been the major driver of the recent increase in planted forest area (FAO 2006b).

The term "planted forests", as used by the FAO, includes commercial plantations and the planted component of semi-natural forest. The FAO global forest statistics do not include "trees outside forests", i.e. areas planted with trees that are smaller than 0.5 ha in size, or stands having a canopy cover of less than 10 percent. These areas (e.g. open woodlands and agroforestry systems established by smallholders) provide tree products and services that support the livelihoods of local people. More than one billion smallholders grow trees; the number of trees integrated with crop cultivation and other farm activities in order to provide products and valuable environmental services is increasing (FAO 2005). According to Zomer et al. (2009), agricultural areas with less than 10 percent canopy cover account for 1.2 billion ha, equalling 54 percent of the global agricultural area.

In the present report, the exchange of forest reproductive material – or germplasm (that is, seeds, cuttings or other propagating parts of a tree) – needed for regenerating natural forests and establishing plantations and agroforests is discussed. Only a small number (less than 140) of the world's 50,000 or so tree species are being used in commercial forestry, and current breeding efforts focus on even fewer taxa (National Research Council 1991). However, many more tree species are useful for humans in terms of their non-wood products or environmental services, even though they are largely undomesticated.

Seeds of tree species commonly planted in natural forests, commercial plantations and farms are ideally obtained from selected seed stands or seed orchards which are managed specifically for seed production. Performance of such genetic material is usually tested in provenance trials across different sites and climatic conditions. In many countries, however, seed production areas are unable to meet demand and seeds are thus also collected from wild, untested populations or scattered trees on farms, increasing risks of failure and low yield from poor seed sources. Large-scale multiplication through vegetative techniques such as micropropagation (microcuttings or somatic embryogenesis) is also increasingly deployed in forestry to clone superior trees or to propagate new genotypes otherwise available only in limited quantities (FAO 2004).

Many tropical tree species produce recalcitrant seeds, difficult to collect, transport, process and store due to their lack of dormancy and sensitivity to both desiccation and low temperature. Around 70 percent of tree species in humid tropical forests have seeds of recalcitrant or intermediate behaviour (Sacandé et al. 2004). This remains a major limitation in the planting of these species, despite recent efforts to better understand their biology. For some tropical trees, the collection of naturally regenerated seedlings (wildings) from forests may be an alternative option to obtain planting stock, although this can be time consuming and expensive.

Tree species differ from other plant species in many ways. Trees are typically long-lived, highly heterozygous organisms with high outcrossing rates and long-distance dispersal of pollen and seeds. As a result of these features, trees have the highest levels of genetic diversity of any group of plants;

more than 90 percent of this variation is found within populations (Hamrick et al. 1992). Despite this, it is important to pay close attention to genetic diversity when sourcing germplasm for tree planting, as strong inbreeding depression (i.e. the process by which self- or related-mating leads to decreasing heterozygosity and the 'exposure' of deleterious mutations) is possible in small and fragmented tree populations. The gene pools of many tree species in breeding programmes are still semi-wild, while only a few trees, such as poplars (*Populus* spp.) and a small number of fruit trees [e.g. apple (*Malus* spp.), mango (*Mangifera indica*) and pears (*Pyrus* spp.)], have been domesticated to a level similar to that of agricultural crops.

1.2. Focal tree species

Movement of tree germplasm has a long history but comprehensive data is unavailable on either past or current introductions. Concerning the current status of the conservation and use of forest genetic resources, various information systems and other databases do exist but they do not provide harmonized information and often focus on specific tree species and their genetic resources (cf. Palmberg-Lerche 2007). Furthermore, a global assessment of forest genetic resources has not yet been conducted, but a process has been initiated by the FAO to prepare the State of the World's Forest Genetic Resources report by 2013.

In this report, we provide available information on the movement of tree germplasm focusing on selected groups of tree species important for human well-being and which provide both wood and non-wood products. These groups include 1) fast-growing plantation tree species, 2) tropical hardwoods, 3) agroforestry tree species, and 4) temperate and boreal tree species. Tables 1.1-1.4 in Appendix 1 provide summary information (uses, natural distribution and major planting regions or countries) on the selected tree species in these groups

CHAPTER II: USE AND GLOBAL MOVEMENT OF FOREST REPRODUCTIVE MATERIAL AND THE BENEFITS REALISED

2.1. Exploration, assessment and movement of tree germplasm

2.1.1. Fast-growing plantation tree species

Systematic exploration and assessment of various fast-growing tree species for industrial and smallholder planting efforts only began about 50 years ago. Most of these efforts have focused on species such as acacias (*Acacia* spp.), eucalypts (*Eucalyptus* spp.) and pines (*Pinus* spp.) which are the most common plantation tree species across tropical, sub-tropical and Mediterranean regions of the world today. However, the germplasm of these tree species have been moved between countries and regions for a long period of time. The first introductions of acacias and eucalypts from Australia, Indonesia and Papua New Guinea (PNG) to other countries have been poorly documented but it is assumed that the first movements began in the 19th century. The first introductions of acacias and eucalypts from Australia, Indonesia and Papua New Guinea (PNG) to other countries have been poorly documented but it is assumed that the first movements began in the 19th century. Tasmanian blue gum (*Eucalyptus globulus)*, for example, was widely planted throughout the temperate regions of the world during the 19th century and, as a result, its landraces are now established in many countries (Freeman et al. 2007).

In the case of acacias, exploration and testing efforts during the past decades have largely focused on *Acacia mangium*. Numerous genetic evaluation trials, including provenance and provenance-progeny trials, as well as trials of seed sources, including exotic land races and seed orchards, have been established for this acacia species throughout the tropics. The first comprehensive assessment effort were the FAO/CSIRO(Commonwealth Scientific and Industrial Research Organisation)-coordinated international provenance trials established in South and Southeast Asia, Australia and Fiji (see Harwood & Williams 1991) and in PNG (see Vercoe & McDonald 1991) in the 1980s. *A. mangium* seed is not readily available from wild populations and the collection of seed from the best provenances in PNG is a logistically challenging exercise due to the remote locations and poorly developed transport infrastructure. However, the Australian Tree Seed Centre (ATSC), in collaboration with its partners, has been collecting and dispatching significant quantities of *A. mangium* seed since the 1980s (Table 2.1). The ATSC still holds large stocks of wild acacia seed, which is now in low demand, indicating that the breeding programs and collections from plantations in different countries are producing sufficient amounts of seed to satisfy the high seed demand for operational planting (*A. mangium* and *A. crassicarpa* have not proved readily amenable to operational clonal forestry because of the rapid maturation of clonal hedge plants, leading to poor rooting vigour of cuttings).

Major recipient countries of acacia germplasm have included Indonesia, Malaysia, Thailand and Vietnam. Active tree improvement programmes for *A. mangium* are being carried out in a number of countries including Australia, Indonesia (Nirsatmanto et al. 2004), Malaysia, the Philippines (Arnold and Cuevas 2003) and Vietnam. Most of these programmes have progressed beyond the first generation of progeny trials and have established clonal seed orchards and second-generation progeny trials. Since 1995, the international availability of genetically improved acacia seed has improved significantly. Currently, most new acacia plantations established in the tropics are of improved seed or clonal material, which is also available for hybrids of *A. mangium* and *A. auriculiformis*.

In the case of *E. globulus*, systematic assessment efforts started in the 1970s. The first provenance collection was made by the Forestry Commission of Tasmania in 1978; this material provided seeds for a major series of provenance trials. From 1987-1988, ATSC also conducted comprehensive individual-family collections, yielding 616 families from 49 localities across most of the natural range of the species (Jordan et al. 1993). Later on, several other major family collections were made to expand base populations for breeding (Gardiner 1994). Bulk collections of seed from the superior provenances of *E. globulus* by commercial seed collectors also continue to meet the demand created by the establishment of large-scale plantations in Australia and other countries, notably Argentina and Chile.

Tree breeding of *E. globulus* had already begun in Portugal in 1966, initially based on phenotypic selections from local landrace populations originating from southern Tasmania (Freeman et al. 2007). This material was later supplemented by family-based collections from Australia. Breeding programmes for *E. globulus* have since been established in several other countries. The ATSC collections from 1987-1988 comprise a major part of the base populations for breeding programmes in Argentina, Australia, Chile, Ethiopia, Portugal, Spain and Uruguay (Potts et al. 2004). Some of these breeding programmes have now moved into the second or third generation of selection. A regional summary of ATSC dispatch records of *Eucalyptus globulus* from 1981 to 2009 is provided in Table 2.2.

E. camaldulensis is another eucalypt species which has been widely explored and used in plantations. In fact, today it is probably the most widely planted tree species in the world. The species has the widest natural distribution range of any eucalypt, covering tropical, Mediterranean and temperate climates in Australia. In the 1950s, early testing efforts revealed a significant genetic variation in growth rate, alkalinity tolerance and stem straightness among different populations of the species. This led to the initiation of a large FAO-coordinated investigation of provenance variation in *Eucalyptus camaldulensis* in 1962, with range-wide collections undertaken in 1964 (Eldridge et al. 1993). Until 1972, most of the world's extensive plantings of *E. camaldulensis* were sourced from the Murray Darling drainage system (Turnbull 1973a). This changed once results of the 1964 provenance trials were published, as it was then widely recognised that tropical sites should be planted with material from northern Australia. Generally, *E. camaldulensis* provenances from southern Australia do not perform well in tropical environments and the tropical provenances perform poorly on Mediterranean and temperate sites.

Since the 1960s, the ATSC has dispatched more seedlots of *E. camaldulensis* than any other taxon. Some 16,000 seedlots have been sent since 1980 when the computer database was commissioned, but several thousand seedlots are estimated to have been dispatched in the preceding 15 years (table 2.3). The ATSC has also dispersed a large number of selected bulks and individual seedlots of *E. camaldulensis* during the last decade. Historically, the regions most actively seeking *E. camaldulensis* germplasm have been South Asia (particularly India) and Southeast Asia (especially Vietnam, Thailand and the Philippines). During the last five years, demand for bulk seed has increased in several countries in these regions. The demand has been met by a combination of wild seed and genetically improved seed from seedling orchards in Australia and other countries. Clonal plantations of *E. camaldulensis* and its interspecific hybrids with several other tropical and subtropical eucalypt species are well developed in countries such as China, India and Thailand (Varghese et al. 2008).

In addition to acacias and eucalypts, several tropical pine species from Mexico and Central America are being used in plantations all over the world. The region is also considered as a centre of diversity for the genus *Pinus,* with more than 100 species globally (Dvorak 2000a). In Mexico, one of the first collections of pine germplasm (*Pinus patula*) was made in the early 1900s and the material was sent to South Africa (Butterfield 1990) and subsequently used for establishing the first pine plantations in the country. These plantations also served as a source of genetic material for other countries in southern Africa for many years (Butterfield 1990, Poynton 1977). Exploration of pine germplasm began in earnest in Mexico and Central America from the late 1950s to the early 1970s. These collections included *P. caribaea, P. oocarpa*, *P. greggii* and *P. patula* (Schuckar, per. comm. 2000, Coetzee 1985, Darrow and Coetzee 1983, Barrett 1972, Mortenson 1969).

In the 1980s, organizations like Camcore[2] (International Tree Conservation & Domestication Program), North Carolina State University and DANIDA (Danish International Development Agency)

[2] For further information, visit www.camcore.org.

began researching collections of pine species in México and Central America. Since that time, Camcore has been the primary agency devoted to the testing and development of Central American and Mexican pine species. Camcore, which is financially supported mainly by the private sector, has worked with 25 different pine species from the region. It began its mother-tree seed collections of *P. tecunumanii* in 1981, *P. oocarpa* and *P. caribaea* in 1982, *P. maximinoi* in 1984, *P. patula* in 1986 and *P. greggii* in 1987. Since the early 1990s, Camcore has been distributing quantities of seeds for research to its member organizations (mainly private companies) as part of a series of international provenance and progeny trials and developments of *ex situ* conservation stands (Dvorak et al. 1996). Final assessment of these trials was made for survival, productivity and stem form at the age of eight years. Results of the trials have been published in Gapare et al. (2001), Dvorak et al. (2000b, 2000c, 2000d, 2000e, 2000f, 2000g), and Hodge & Dvorak (1999, 2001).

Camcore has collected seeds from 191 provenances of the six Mesoamerican pine species included in this report and established provenance or progeny trials at 823 locations in ten countries. Genetic diversity assessments using molecular markers have also been made for all six pine species by various authors to assist governments and the private sector in the prioritization of gene conservation efforts. The origin and plantation area of six important Mesoamerican pines is provided in Table 2.4.

P. patula has been planted extensively outside Mexico, notably in Southern and Eastern Africa and Colombia, where it has undergone intensive tree improvement for growth and wood traits. Researchers in Mexico, working through the Camcore membership in South Africa, brought first and second generation *P. patula* selections from South Africa back into Mexico in the mid-1990s, in hopes of harnessing the genetic gain that had been expressed there (Saenz-Romero et al. 1994). These re-introductions of pine germplasm into Central America and Mexico from the private sector in long-standing receptor countries continue today.

Outside Central America and Mexico, long-term advanced-generation tree improvement programs exist for *P. caribaea* in Australia. *P. patula* breeding programs in South Africa and Zimbabwe are well into their second or third generation of breeding. Moving into the third generation of breeding in South Africa has been hampered by high mortality in young progeny trials due to Pitch canker. The original genetic base for the advanced generation of *P. caribaea* and *P. patula* programmes pre-dates the collections made by Camcore. Tree improvement programmes based on Camcore material for *P. greggii, P. maximinoi, P. oocarpa and P. tecunumanii* are at the stage where second-generation field trials are just now being established (Camcore Annual Report 2007).

2.1.2. Tropical hardwoods

Timber of several tropical hardwood species has been extracted from natural forests for centuries. While natural forests still supply large amounts of tropical timber, industrial and smallholder plantations are increasingly becoming a significant and more easily accessible source of tropical timber. Several tropical hardwood species also provide important non-wood products, such as oil, medicine, nuts and fruits.

The potential of many tropical hardwood species for plantation forestry was recognised early in many countries. Teak (*Tectona grandis*) is a well-known example of such species. Teak seed was transferred from Asia to Africa and Central America more than one hundred years ago, with reports of successful introductions to Nigeria (cf. Egenti 1978), West Indies, Trinidad and PNG (Cameron 1968) in the late 19th century. At the beginning of 20th century, the species was also introduced to Tanzania, Togo (Chollet 1956) and Ghana. During the following decades, teak was further introduced to Cote d'Ivoire (cf. Tariel 1966), Sudan (cf. Hall & Williams 1956) and several Central and South American countries.

The large-scale export of teak timber extracted from natural forests in India and Thailand ended decades ago, and today, only Myanmar remains the major exporter of large size logs from natural teak forests. Subsequently, the demand for cultivated teak timber has increased dramatically over the past decades. Large areas of teak plantations have been established within the species' natural distribution area in India, Thailand and Indonesia (Ball et al. 2000), as well as outside its natural distribution area since the 1950s. It has been estimated that, in 1995, teak constituted 9 percent of the total plantation area in Central America and 27 percent in the moist region of West Africa (Ball et al. 2000).

Systematic exploration of teak genetic resources started several decades after the first introductions of teak to other countries and regions. One of the first provenance trials was established in 1930 in India (Mathauda 1954) and Indonesia (Java). Testing efforts increased between the 1950s and 1970s, revealing a range of moderate to significant differences between provenances which were often manifested after many years of growth rather than immediately after planting. Experiments in Thailand are described by Kjær & Kaosa-ard (unpublished note); Graudal et al. *(*1999) and Kaosa-ard (1999). From 1971 to 1975, a large international effort was launched to test teak provenances globally (Keiding et al. 1986), with the objective to explore provenance variation and to identify superior provenances for procurement of seed or other propagation material for plantation or improvement programmes. Coordinated assessments of these trials were carried out from 1982 to 1987 and again during the years from 1991 to 1995. The results of these assessments are reported in Keiding et al. (1986) and Kjær et al. (1995). Results of other teak provenance trials are also reported in various publications (e.g. Egenti 1978).

The introductions of teak germplasm from multiple sources have contributed to the development of landraces in parts of the tropics. The origins of these landraces are poorly documented, but historical records have shed some light on prominent routes of introduction and likely sources of germplasm. In Central America, the first introductions of teak occurred in Trinidad, where the seed probably originated from lower Myanmar ('Tenasserim') (Keogh 1980). Later, seeds were also exported to Trinidad from India, but most of the present teak plantations in Trinidad are most likely of the Tenasserim material (Keogh 1980). A few decades later, teak was introduced to Panama. It is believed that a large part of the present plantations in Panama originate from a small seed lot imported from Sri Lanka (presumably of East Indian origin) in 1926. Using this material, approximately 40 trees were raised at the Canal Zone Plant Introduction Gardens of Panama. For decades, seed collected from these trees was used for further teak planting in Panama (Gutierrez and Cordovez, pers. comm. cited by Keogh 1980). Seeds were exported from Panama to Nicaragua in the 1940s, but other imports may have taken place from Honduras and/or Trinidad (cf. Keogh 1980). In addition, teak was reportedly introduced from Panama to Guatemala, though other sources are also possible (Keogh 1980). In Honduras, teak seed was imported from another botanical garden, the Royal Botanical Garden of Trinidad, where the seed had been collected from only two mature trees (cf. Keogh 1980). Such collections have acted as bottlenecks, reducing the genetic diversity of teak germplasm during the introduction process (e.g. Kjær & Siegismund 1996).

In East Africa, the Kihuwi, Bigwa and Mtibwa seed sources of teak in Tanzania have provided large amounts of seeds for plantations in the region, and later in West Africa. These landraces are reported to originate from multiple and rather diverse seed sources, including Southwest India ('Nilambur'), Myanmar and possibly Java in Indonesia (Wood 1967). The African landraces have a relatively high level of genetic diversity (Kjær & Siegismund 1996), but no clear genetic relationship with teak populations in South India has been found (Fofana et al. 2008). Several other studies on genetic diversity of teak have also been conducted, (e.g. Kertadikara & Prat 1995, Nicodemus et al. 2003 and Shrestha et al. 2005) but none offer decisive information on the origins of the African landraces.

In addition to Asia, Africa and Central America are also home to several other tropical hardwood species. In Central America, mahogany (*Swietenia macrophylla*) and Spanish cedar (*Cedrela odorata*) are the most important native timber species, which have been increasingly planted within the region. Since 1980, the demand for seeds of native tree species has increased considerably in Central America as a result of new research, spearheaded by CATIE (Tropical Agricultural Research and Higher Education Center) and other research institutes, on native tree species and their potential to provide high quality timber with a relatively short rotation period. This offers income opportunities for farmers to fill a market niche not occupied by large forestry companies, which traditionally focus on growing exotic trees species, such as acacias and eucalypts, for paper mills.

The genebank of CATIE (BLSF or Latin American Tree Seed Bank) was created in 1967 and initially dealt only with exotic tree species planted in Central America. The main objective of BLSF was to collect or import seedlots of exotic tree species, primarily for research purposes. As the demand for the seed of native tree species increased, research institutes and genebanks in Central America, including CATIE, progressively expanded their focus to include native species as well. In addition, public awareness of the benefits and value of growing native species has been increasing in many countries in the region. A list of the most important native species exchanged by the BLSF in 2008 and the quantities exported is provided in Table 2.5.

Today, mahogany and Spanish cedar are also planted widely in other regions, such as Africa and Asia. The importance of mahogany, Spanish cedar and teak as plantation species outside their natural distribution range clearly demonstrates the benefits exchanging tree germplasm can bring to countries, including to their smallholder farmers.

2.1.3. Agroforestry tree species

Small-scale farmers have planted trees as part of their farming systems for centuries, if not millennia. During the process, several tree species have been domesticated and tree germplasm has been exchanged among communities, countries and regions. However, more systematic documentation, analysis and further improvement of various agroforestry systems have only been carried out recently, during the past 40 years or so.

Small-scale farmers in the tropics rely on various tree species to support their needs, and information on the exchange of a wide range of taxa for a variety of functions is required in order to properly understand the benefits of germplasm transfer. However, detailed information on exchange and movement of tree germplasm and species of interest to smallholders is quite limited. For this report, two existing databases created and maintained by the World Agroforestry Centre (ICRAF) [i.e. the Agroforestree Database (AFTD; www.worldagroforestry.org/Sites/TreeDBS/aft.asp) and the Tree Seed Suppliers Directory (TSSD); www.worldagroforestry.org/Sites/TreeDBS/tssd/treessd.htm] were surveyed to obtain relevant information. The AFTD contains information on the native and exotic distributions of more than 500 trees important to smallholders, while the TSSD provides data on more than 100 suppliers of seed (and occasionally vegetative material) for several thousand tree species. The suppliers listed in the TSSD are located in over 60 countries, the majority of which are in the tropics.

In order to provide insight based on the different benefits received by smallholders from cultivating trees, database searches were stratified across four categories of tree use: 1) species used for timber production; 2) trees cultivated for fruit consumption; 3) taxa used for medicinal purposes (bark, roots, leaves, etc.); and 4) trees grown for fodder and/or soil fertility improvement (these uses were considered together, as many species are planted for both purposes). Thirty key species were selected for each category of use, with 120 surveyed taxa in total (Table 2.6). The results of searches indicated high levels of past international transfer of germplasm for all use categories; each species was recorded as having been distributed in 21 countries beyond its native range, on average (Table 2.7). With such wide distribution of germplasm by all categories of tree use, the importance of future material exchange at an international level for smallholder farmers is evident, as new improved material is selected and developed for different functions.

Search results suggest that species used for fruit and fodder/soil fertility improvement have been distributed to more exotic locations (both, on average, to 25 other countries) than timber and medicinal trees, with a greater proportion of the current total range (indigenous and exotic distribution) of the former two categories being exotic (74 and 70 percent, respectively). According to the database entries of the 120 taxa surveyed, *Casuarina equisetifolia* was the timber species distributed to most countries outside its native range, with *Azadirachta indica*, *Mangifera indica* and *Leucaena diversifolia* being the most widely distributed medicinal, fruit and fodder/soil fertility species, respectively (Table 2.8).

2.1.4. Temperate and boreal tree species

In the 18th century, seeds of forest trees, mainly Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), European larch (*Larix decidua*) and oaks (*Quercus* spp.), were already widely traded across European countries; the city of Darmstadt in southern Germany was the major trading centre (Tulstrup 1959). Exploration and assessment of germplasm of temperate and boreal forest tree species also started more than two hundred years ago (see König 2005 for a comprehensive review on provenance research). One of the first efforts to test seeds of a forest tree from different sources took place in France from 1745 to 1755. This effort focused on Scots pine using seed lots from different parts of Europe (the Baltic States, Russia, Scotland and several Central European countries) and attempted to identify the best seed sources for growing tall, straight trees for ship making. The results of the test were never published; nonetheless, it can be considered as a starting point for modern provenance research and of understanding the role of climate and site conditions in influencing traits such as growth and stem form (cf. König 2005). Soon after this, basic principles for introducing tree species and provenances from North America to Germany, emphasizing matching of climatic and site conditions, were also formulated (von Wangenheim 1787, cited by König 2005).

Early testing of different seed sources in Europe revealed the existence of "geographical races" of tree species and that the origin of the seed had a major influence on the performance of tree planting efforts. Throughout the 19th century and early 20th century, seed of forest trees was transferred across countries in large quantities in Western and Central Europe, as well as in southern Scandinavia, while little attention was paid to the origin of the seed, despite the fact that its importance was already known from both practical experiences and scientific studies. The demand for seed was high as artificial regeneration had become a common practice in many countries to reforest overexploited forests. As a consequence, the reforestation efforts were not always successful and several countries tried to limit the use of foreign or unknown seed sources. The Swedish forestry administration issued warnings on the use of foreign seed in 1882 and concerns on the uncritical use of foreign seed were also raised in Germany in 1904 (König 2005).

At the beginning of the 20th century, more systematic assessment efforts were initiated for several tree species in Europe (see König 2005). The first international provenance trial for Scots pine was established in 1907, under the auspices of the International Union of Forest Research Organizations (IUFRO), using 13 provenances from different European countries. As Scots pine has a vast natural distribution area across Europe and northern Eurasia, more provenance trials were needed and a second set of the IUFRO trials was established in 1938 and 1939 with 55 and 23 provenances, respectively. Moreover, a third IUFRO trial was established in 1982 with 20 provenances. Additional trials for Scots pine were also planted in other countries (e.g. in Russia in 1910 to 1916, in Sweden in the 1950s and in the USA in 1960s) (König 2005). As part of the IUFRO collaboration, an international provenance trial was also established for Norway spruce in 1938. Later, another trial for Norway spruce was established in Germany from 1968 to 1969 and the second IUFRO trial in 1972 (in Europe and Canada). Provenance trials were also established for several other native tree species, such as silver fir (*Abies alba*), European larch (*Larix decidua*), sessile oak (*Quercus petraea*) and pedunculate oak (*Q. robur*), as well as introduced tree species [e.g. grand fir (*Abies grandis*), Sitka spruce (*Picea sitchensis*) and Douglas-fir (*Pseudotsuga menziesii*)]. Subsequently, several European countries launched breeding programmes for many of these tree species the 1950s and 1960s.

In the 19th century, the exploration efforts were extended to North America and large quantities of seed of many North American tree species were shipped for ornamental planting in other regions around the world. Much of this movement of forest reproductive material remains undocumented. Several North American tree species were also tested for forestry in Europe before they were assessed for this purpose in their native environments. At least 25 North American tree species are now used for forestry in other regions (Rogers and Ledig 1996). In the UK, for example, the introduction of North America tree species for testing is well documented [e.g. Douglas-fir in 1827, grand fir and Sitka spruce in 1831 and western hemlock (*Tsuga heterophylla*) in 1851] (Samuel 2007). Today, Douglas-fir is an important tree species in France and Germany, Sitka spruce in Iceland, Ireland and the UK, and lodgepole pine (*Pinus contorta*) in Sweden. Most of the North American species introduced to other regions also remain important forestry species in Canada and the USA.

In Canada, the first provenance trials of native tree species were established for spruce species (*Picea* spp.) in the 1930s and 1940s, and for jack pine (*Pinus banksiana*) and red pine (*P. resinosa*) in the 1950s (Anon. 1996, D. Simpson pers. comm.). The exploration and testing of various exotic tree species had begun even earlier (from 1900 to 1910) in the western prairie region, for use in shelterbelts and for horticultural purposes (Fowler 1974). Some of the earliest trials involved exotic tree species, such as Norway spruce (1924), European larch species (1930) and exotic pine species (1936). Obviously, these efforts involved importing seeds from other regions, especially from Europe, but no documentation on this is available.

In the USA, the foundation for tree improvement was laid in the 1920s and 1930s. In the southern USA, one of the first provenance trials, established in 1926, included four provenances of native loblolly pine (*Pinus taeda*) (Rogers and Ledig 1996). In the north-western states of the country, the first seed source studies focused on Douglas-fir, but it was only in the 1960s when tree improvement programmes began (Duffield 1959). By the 1980s, there were 125 separate breeding programmes for Douglas-fir in Oregon, Washington and British Columbia (Johnson 2000). Other tree species received much less attention in the Pacific Northwest, but exploration, assessment and improvement programmes were undertaken to varying degrees for Lawson's cypress (*Chamaecyparis lawsoniana*), Sitka spruce, lodgepole pine, sugar pine (*P. lambertiana*), western white pine (*P. monticola*) and western hemlock.

In Canada, exploration, testing and breeding of Douglas-fir also began in the 1950s in British Columbia (Orr-Ewing 1962). Other testing and tree improvement projects in British Columbia included western larch (*Larix occidentalis*), spruce species (*Picea* spp.), ponderosa pine, western hemlock, western red cedar (*Thuja plicata*) and red pine (*Pinus resinosa*). In Eastern Canada, the primary focus for early exploration and testing was spruce species with range-wide provenance trials established for black spruce (*P. mariana*), red spruce (*P. rubens*) and white spruce (*P. glauca*). Provenance trials with native and exotic *Larix* species were also established in Eastern Canada.

In Canada and the USA, it was only in the 1950s when tree improvement and genetic research programmes began to make rapid progress. Before 1960, there was no genetically improved seed available for nurseries and all seedlings for planting were produced from "woods-run" seed collections with little control over seed quality (Dorman 1974). By the mid-1970s, much of the seed used for tree planting in the southern USA was from genetically improved seed orchards. On average, for each of the past five years, approximately 500,000 hectares of loblolly pine and 80,000 hectares of slash pine (*Pinus elliottii*) were planted in the southern United States [US Department of Agriculture (USDA) Forest Service data], all with genetically improved seedlings (McKeand et al. 2003). By the early 1970s, it was clear that native tree species were appropriate for most situations in Canada and seed transfer rules within the country were developed and followed in much of the country (e.g. Cheng and Yanchuk 2006).

2.2. Production, documentation and use of forest reproductive material

2.2.1. Sources of reproductive material and types of producers

Globally, seed remains the most common type of forest reproductive material, and it is obtained from a variety of sources, such as wild stands, selected seed stands, seed orchards, research trials, plantations and even individual trees on farms, depending on tree species and countries. There is no clear pattern among different groups of tree species (i.e. fast-growing plantation tree species, tropical hardwoods, agroforestry tree species, and temperate and boreal tree species) on how their seed is sourced, but there are differences in the availability of seed in different countries and regions. Tree seed crops have a high year-to-year variation, and subsequently, the need to maintain seed storage capacity and maximise harvesting efforts during good seed crop years requires considerable resources.

In the case of acacias and eucalypts, seed collected from natural populations has been a major source of reproductive material but the seed is increasingly becoming available from plantations and seed orchards. A summary of major seed collections of the two acacia species (*A. mangium* and *A. crassicarpa*) is presented in Tables 2.9 and 2.10. Seed collections of *A. mangium* have been undertaken periodically since the 1980s, driven by seed demand for large-scale planting and breeding programmes (Pinyopusarerk et al. 1993). Significant seed production capacity for *A. mangium* exists in Australia and Indonesia, with additional material available from China, the Philippines and Thailand. Though production capacity is overall high, there are periodically localised shortages of *A. mangium* seed caused by sporadic production and difficulties in securing exports from some countries. Seed of this species is typically not certified, and there have been some reports of poor vigour and poor tree form from seed purported to be from seedling seed orchards. An important determinant of nursery success in this species is the application of the correct pre-treatment (either boiling water or hot water soak, depending on seed coat hardness).

Similarly with acacias, periodic seed collections have also been carried out for eucalypts. Until 1972, most of the world's extensive plantings of *E. camaldulensis* had been sourced from the Murray Darling drainage system (Turnbull 1973a). The seed collections were later expanded, after the publication of the results from provenance trials that highlighted the variability in performance across different provenances of *E. camaldulensis* (see Table 2.11). In case of *E. benthamii*, which has a very limited natural distribution in Australia, the seed collections have relied on a very few natural populations (Table 2.12). The seeds have been collected by ATSC from a total of only 90 mother trees, demonstrating how narrow the genetic base of this species is. The wild populations of the species are vulnerable and difficult to access; thus, since 2003 the seed has predominantly been collected and dispatched from Australian seedling seed orchards and seed production areas established with seeds of the earlier collections. With regard to *E. globulus*, the provenance collection made by the Forestry Commission of Tasmania in 1978 provided seeds for the first major series of provenance trials and was later integrated into more comprehensive collections by ATSC (Jordan et al. 1993, Gardiner 1994). A summary of important collections for *E. globulus* is presented in Table 2.13.

In the case of Central American and Mexican pine species, tree improvement programmes have made available better quality seed (Table 2.14). Seeds of Caribbean pine (*P. caribaea*) and Mexican weeping pine (*P. patula*), produced in commercial seed stands and seed orchards, are readily available on the world market from both the public and private sector. The national seed bank (ESNACIFOR or National School of Forest Sciences) and a private seed dealer (SETRO or Tropical Seeds Company) in Honduras also have the capacity to sell large quantities of Caribbean pine seeds collected from natural stands. Seed from seed stands and improved seed orchards are also available from Queensland, Australia, and from Norske Skog and Schuckar Seed Company, private organizations with orchards in the states of Minas Gerais and São Paulo, Brazil, respectively. A large (> 100 ha) Caribbean pine seed orchard, owned by a quasi-state organization, PROFORCA (Productos Forestales de Oriente C.A), also exists in west-central Venezuela and in good seed years, it produces more than 2000 kg of seed. Most of the seed produced is for local use by the company in Venezuela. Only recently has PROFORCA begun selling seeds, and only to other organizations within the country. Improved seed of Mexican weeping pine is available from the private sector in South Africa [mainly Mondi, Sappi and Komatiland Forests (KLF)], as well as the Forest Research Centre (FRC) in Zimbabwe. In the case of Gregg's pine (*P. greggii*), there is only one seed orchard, located near Sabie, South Africa and managed by Mondi (Vermaak, pers. comm. 2009).

ESNACIFOR and SETRO in Honduras and the national seed bank in Nicaragua (CMG&BSF) or Center for Genetic Improvement and & Tree Seed Bank) sell seeds of thinleaf pine (P. maximinoi) and Tecun Umán pine (P. tecunumanii) from natural stands, with Honduras having a much greater capacity to provide seeds than Nicaragua. The national seed banks in Guatemala and the Forest Genetic Centre in Mexico currently do not provide commercial quantities of thinleaf pine and Tecun Umán pine seeds for sale. Several forestry companies have established seed stands and orchards for the two pine species in Brazil, Colombia and South Africa, but they only produce enough seeds for their own local needs. The Schuckar Seed Company in Saõ Paulo commercially sells Tecun Umán pine seed, which originates from collections in Honduras established in the 1960s. The FRC in Zimbabwe also sells small amounts of thinleaf pine seed from orchards.

ESNACIFOR, SETRO and the Schuckar Seed Company are the main providers of Mexican yellow pine (*P. oocarpa*) seed in the world. There is a growing interest from the private sector for pollen of this species to be used in hybrid crosses due to the species' resistance to the Pitch canker fungus. As a result, Camcore has collected research quantities of pollen from Mexican yellow pine in Guatemala for its pine hybrid program (Camcore Annual Report 2007).

The seed of tropical hardwood species is often sourced from wild stands, plantations and research trials, as there are fewer improved seed sources available as compared to the fast-growing plantation tree species. However, it is fairly common that the seed supply is unable to meet the demand, thus limiting the establishment of new plantations for tropical hardwoods. In the case of teak, for example, tree improvement programmes have been initiated in many countries, but the results have been somewhat disappointing. Kjær & Suangtho (1997) found that the fairly large selected seed production areas in Thailand could only supply a minor part of the seed used for raising teak seedlings in nurseries. This results from very low rates of seed production per teak tree. This study also found that large quantities of teak seedlings were raised from seed collected from plantations near the central nurseries due to lack of seed from improved seed sources. An additional problem for successful tree improvement of teak is the difficulty in collecting a sufficient number of seeds per tree to establish large-scale progeny testing at multiple sites.

Deployment of clonal seed orchards is by far the most common way for procuring improved seed for the establishment of tree plantations. For teak, however, the reliance on clonal seed orchards has caused severe problems for the successful deployment of selected material from the tree improvement programmes in Thailand, India and Indonesia. The main problem is low seed yield per tree in the clonal seed orchards in Southeast Asia (Kaosa-ard et al.1998, Nagarajan et al. 1996, Varghese et al. 2005, Palupi & Owens 1996). Combined with the low and sporadic germination behaviour of teak seed, common in commercial scale nurseries, this leads to a fairly low multiplication factor. Wellendorf & Kaosa-ard (1988) calculated that one ton of seed only produced about 92,000 seedlings. With an average spacing of 1,100 seedlings per ha, this means that about 12 kg of seed is needed for establishing one hectare of teak plantation. Given the low average productivity of clonal seed orchards in Thailand (probably below 100 kg of seed per ha), this means that each hectare of clonal seed orchard can provide seed for establishment of less than 10 ha of new plantation, annually. With the annual seed demand of 240 tons in Thailand alone (Kjær & Suangtho 1997), it has been difficult to meet the demand for improved seed in Thailand, and the situation is likely to be similar in Indonesia and India. To overcome these difficulties, the development of vegetative propagation methods for teak was started (e.g. Guptha et al. 1980, Kaosa-ard et al. 1987 and Kaosa-ard 1990). These efforts yielded positive results (Kaosa-ard et al. 1998), opening the route for large-scale deployment of the best genetic resources, linking propagation efforts directly to testing and breeding programmes (Goh & Monteuuis 1997).

In the case of agroforestry tree species, the lack of adequate smallholder "germplasm delivery systems" is a major limitation for tree planting efforts. Centralised models of delivery, such as those based around National Tree Seed Centres (NTSCs), were heavily supported by donors in the 1980s and 1990s. However, it has been estimated that, although NTSCs are appropriate for supplying the plantation industry, they have delivered less than 10 percent of the smallholder demand for tree seedlings and seed. This is because small-scale farmers are widely dispersed and require only small volumes of particular species, making them expensive to reach (Graudal & Lillesø 2007). In Africa, low tree seed delivery from centralised suppliers to smallholders mirrors the situation observed in the crop sector, where the majority of small-scale farmers use their own saved seed for future planting (Jones & Rakotoarisaona 2007). A trend in the 1990s to provide donor support to more decentralised models of tree germplasm supply, based around non-governmental organization (NGO) delivery, appears, in general, not to have fared much better, due to a range of factors: the restricted timescale of projects, the lack of attention to the promotion of genetically superior material, and insufficient technical knowledge in handling germplasm, leading to poor physiological quality.

Local, private seed suppliers, who may ultimately be able to operate on a more sustainable basis, have been discriminated against by NTSCs that hold both 'productive' and 'normative' functions in supply (that is, NTSCs that both provide seed commercially and help to regulate the sector, resulting in conflicts of interest), and by the common NGO practice of providing free or heavily subsidized planting material. In a survey of NGO distribution to smallholders in Uganda, for example, 71 percent of beneficiaries obtained material free of charge, proving a significant disincentive to the involvement of private dealers (Brandi et al. 2007).

The seed of temperate and boreal tree species used for forestry in Europe and North America is largely obtained from selected seed stands and seed orchards. For some species, such as poplars (*Populus* spp.), reproductive material is produced vegetatively on a large scale. In Canada and the USA, the vast majority of seed is produced in seed orchards run by private companies, industrial co-operatives or government agencies. In Europe, seed orchards are often managed by government agencies or government-owned companies.

However, collection of seed of temperate and boreal tree species from the wild also remains a common practice in several countries. In the USA, significant quantities of hardwood species are planted each year using seed that is not produced in seed orchards. Much of the material produced for forestry purposes comes from collections made in wild stands and sold by state nurseries (Karrfalt pers. comm.). In general, production of seed and other reproductive material of temperate and boreal tree species for forestry purposes is better controlled and documented as compared to material produced for horticultural or landscaping purposes. In Canada and the USA, most of the seed used for forestry is from native species (>95 percent), but landscaping utilizes many introduced tree species. Similarly, in Europe, only 5.2 percent of the total forest area is dominated by introduced tree species (MCPFE 2007).

2.2.2. Documentation and certification schemes

The OECD (Organisation for Economic Co-operation and Development) Scheme for the Control of Forest Reproductive Materials Moving in International Trade was established in 1967; it was fully revised for the first time in 1974. A second full revision was made in 2007 and it became known as the "OECD Scheme for the Certification of Forest Reproductive Material Moving in International Trade", abbreviated to the "OECD Forest Seed and Plant Scheme"[3]. The Scheme defines common harmonised procedures for the production and certification of forest reproductive material.

Currently, 25 countries participate in the Scheme. These include mainly countries in Europe and North America, but three Africa countries (Burkina Faso, Madagascar and Rwanda) have also joined the Scheme. Furthermore, several other countries, especially from the tropical areas of Africa and South America, have expressed interest in the Scheme when determining a domestic system for the certification of forest reproductive material. Taking into account the increased interest from tropical regions, OECD is working on the adaptation of the Scheme to conditions in tropical countries.

[3] For more information on the OECD Forest Seed and Plant Scheme, visit www.oecd.org/tad/forest .

Until 2007, the Scheme included four categories of forest reproductive material:1) source-identified; 2) selected; 3) untested seed orchards; and 4) tested seed orchards. An OECD survey showed that 99 percent of seed certified from 2002 to 2003 was either source-identified or selected. This revealed that seed certified under the two more advanced categories was seldom used for international trade. Therefore, the Scheme revised its categories, keeping only two of the original four (source-identified and selected). There are two types of basic material recognised in the Scheme from which reproductive material can be collected, namely "seed source" and "stand". Other categories such as "qualified" and "tested", which can involve other types of basic material (seed orchard, parents of family(ies), clone and clonal mixture), are under consideration for future inclusion in the Scheme. Different OECD labels are used according to the two categories; the labelled product is then recognised internationally as a guarantee of quality and as a certificate of origin.

In 1999, the Member States of the European Union (EU) adopted a new Council Directive 1999/105/EC on the marketing of forest reproductive material, which is very similar to the earlier OECD Scheme and includes four categories of forest reproductive material: 1) source-identified; 2) selected; 3) qualified; and 4) tested. The types of basic material included in the EU Scheme are seed source, stand, seed orchard, parents of family(ies), clone and clonal mixture. The major difference between the two schemes is that the OECD Scheme is a voluntary scheme for international trade while the EU Scheme primarily regulates domestic trade within the EU. Furthermore, the EU Scheme is a directive that needs to be implemented in the national legislation of EU Member States. The two schemes are further discussed by Ackzell & Turok (2005).

In North America, the OECD Scheme is used in Canada to certify seed for export (although seed is also exported without certification). It is also used to a limited extent in the western United States in Washington and Oregon for seed that is shipped to Europe, but not for seed used in the rest of the country. States in the USA have their own certification systems, by which seed can be certified if it is originating from natural stands, seed production areas or seed orchards (Schmidtling 2001).

Within each Canadian province, the quality and origin of reproductive material for forest plantations is controlled for publicly owned land. All material is registered by provincial governments and can be tracked from source to planting site. Seed transfer rules, including seed planning or breeding zones, are specified in provincial legislation, policies or guidelines. In the British Colombia, for example, tree seed must only be transferred from its source to a planting site in accordance with a set of standards established by the province's chief forester, which are species- and area-dependent (Brian Barber, pers. comm.).

No certification is required by the government for transfer of forest reproductive material among North American countries. In general, the only legal requirements for forest reproductive material moving between any two of the three countries are phytosanitary certificates and import permits. It is the responsibility of individuals or agencies involved in a particular transaction to ensure that seed meets these requirements. Some forest reproductive material is transferred between agencies in accordance with agreements intended to protect the interests of the provider of the forest reproductive material. For example, genetically improved forest reproductive material and its associated intellectual property, developed by the government of British Colombia through its tree breeding programmes, is provided to private seed orchards through material transfer agreements.

With regard to the six Mesoamerican pines included in this report, the private sector outside Central America and Mexico selling commercial quantities of improved pine seeds is not involved with any certification schemes or programmes. Within Central America and Mexico, certification of pine seeds is becoming more important. Both Guatemala and Nicaragua are in the process of certifying several natural stands. In Guatemala, the National Seed Bank in Guatemala (BANSEFOR or Tree Seed Bank) has certified *P. maximinoi* at Coban. In 2009, it will certify the natural stands of *P. oocarpa* at Mal Paso, La Lagunilla, and El Castaño and *P. maximinoi* and *P. tecunumanii* at San Jeronimo for seed production following the schemes developed for seed sources by PROSEFOR (Project on Tree seeds) in Central America (Ramírez, per. comm. 2009). Briefly, the scheme works as follows: a request is made to certify a natural stand or plantation; the prospective site is then described and evaluated by BANSEFOR and, if the stand meets certification requirements, it is registered. The benefit of this process includes better control and monitoring of reproductive material with some level of genetic improvement in order to improve plantation quality and yield for the national forestry incentive program (Ramírez, per. comm. 2009).

In Nicaragua, the government has recently instituted a protocol for the certification of forest seeds, including pines. In 2008, it certified seed production areas of *P. caribaea, P. oocarpa* and *P. tecunumanii* and will expand the certification scheme to include additional areas of *P. caribaea* and *P. tecunumanii* in 2009 (Caballero, per. comm. 2009).

There are currently no certified pine seed production areas in Honduras (Leverón, pers. comm. 2009). In Mexico, there are some efforts to promote certification of forest seeds and laws are now being developed (Lopez-Upton, pers. comm. 2009). However, of the approximately 20 seed stands of *P. patula* in the states of Veracruz and Hidalgo, none are currently certified by any standards (Eguiluz, per. comm. 2009).

In the case of Central American tropical hardwood species, such as Spanish cedar (*Cedrela odorata*) and mahogany (*Swietenia macrophylla*), tree improvement activities are rather limited and most seed is collected from the wild. In Costa Rica, some natural stands of these two species are protected to provide seed for the government nurseries. In the 1990s, the Latin American Tree Seed Bank (BLSF) at CATIE developed guidelines for seed collection with a minimum requisite for all seed sources that seed be collected from at least 20 seed-bearing trees (or from 20 mother trees). BLSF has also developed a strategy for the seed to be certified by the National Office of Seeds (ONS) in Costa Rica. This scheme is based on five categories of forest reproductive material: 1) identified sources; 2) selected sources; 3) seed stands; 4) non-tested seed orchards; and 5) tested seed orchards.

Standard rules of the OECD Scheme are applied in some African countries, even if they are not strictly implemented. Madagascar has participated in this Scheme since 1998 and has fully adopted the rules on Forest Reproductive Material (FRM) moved within local and external seed trade. Of the countries in Eastern and Western African regions, Madagascar is the only one participating in the OECD Scheme. Seeds of *Adansonia digitata* and *Delonix regia* coming from Madagascar and being traded internationally are certified under the OECD Scheme. Moreover, the same system is applied for national trade by the Silo National des Graines Forestières (SNGF). Ethiopia is also using nomenclatures of OECD FRM categories (handled seedlots are certified under identified or tested categories) in tree seeds production and trade. Kenya, too, applies the four categories of the OECD Scheme (identified, selected, qualified and tested). In Tanzania, seed sources are classified, but they do not use the categorization for FRM.

2.2.3. Area of registered seed sources

In 2008, the OECD reported that only 12 countries produced forest reproductive material under the "source-identified" category while other countries did not include this category in their national lists. The area covered within the source-identified category totalled 29.9 million ha, including 210 tree species (OECD 2008). The data in this category is highly variable, with some countries reporting millions of hectares as source-identified. For the “selected” category, the total area of seed sources amounted to about 530 000 ha, including a total of 106 tree species (OECD 2008). Almost all countries produce this type of basic material, with the notable exception of Canada and the United States. The most important tree species in this category are from Europe [i.e. European beech, 129 500 ha; Norway spruce, 93 000 ha; sessile oak, 68 000 ha; Scots pine, 51 600 ha; Austrian pine (*Pinus nigra*), 38 000 ha; silver fir, 33 100 ha; pedunculate oak, 20 100 ha; maritime pine (*Pinus pinaster*), 13 400 ha; and brutia pine (*Pinus brutia*), with 12 200 ha].

Under the category of “untested seed orchards”, 15 countries reported a total of 9 300 ha for 61 tree species, the largest national areas being in Sweden, Turkey and Romania (OECD 2008). Pines (*Pinus* spp.) are by far the most-represented species with more than 6 500 ha in this category, followed by spruces (*Picea* spp.) with 1 160 ha and larches (*Larix* spp.) with 340 ha. These three coniferous genera account for 85 percent of the total untested seed orchard area. Furthermore, eight countries reported stands, orchards or clones under the "tested' category, with a total area of 1 400 ha for 20 tree species (OECD 2008). Germany, Denmark and Hungary accounted for 92 percent of the area and the most represented tree species were sessile oak, Scots pine, Norway spruce, and beech.

In addition to the OECD Scheme, the Ministerial Conferences on the Protection of Forests in Europe (MCPFE) process also collects data on areas managed for seed production at the pan-European level (i.e. also including those countries which are not yet members of the EU and/or the OECD Scheme). The MCPFE process has not defined the "area managed for seed production" in detail, but it basically includes all OECD categories, except the source-identified category. In 2005, there was a total of 528 707 ha of area managed for the seed production of 90 tree species in 38 European countries (MCPFE 2007).

In Canada and the United States, almost all seed used for coniferous forest plantations comes from seed orchards which were initiated by the government, industry or cooperatives (involving industry, universities and government). Many seed orchards are now controlled by the private sector. All material is registered and detailed records are maintained to track origin of parent trees and destination of seed. In Canada, any seed used for forestry plantations on public land must be from registered or documented sources and used within specified seed or breeding zones where planting will occur, unless a specific exception is permitted. In the United States, a significant proportion of hardwood seedlings and cuttings are produced from seed sources that are not registered and are not readily tracked. On private land, adherence to seed zones is voluntary and most planting in the US is done on private land (Karrfalt pers. comm.).

With regard to Mesoamerican pines, BANSEFOR (Guatemala) registered 13 ha of *P. caribaea*, 31 ha of *P. maximinoi*, 99 ha of *P. oocarpa* and 5 ha of *P. tecunumanii* in 2008. In 2009, the goal is to register 20 ha of *P. caribaea*, 80 ha of *P. maximinoi*, 60 ha of *P. oocarpa* and 20 ha of *P. tecunumanii* (Ramírez per comm., 2009). In 2008, INAFOR (National Forest Institute) registered 14 ha, 3.5 ha and 154 ha of *P. caribaea*, *P. oocarpa* and *P. tecunumanii* seed production areas, respectively, in Nicaragua (Caballero, per. comm. 2009). In 2009, seed stands of *P. caribaea* at Alamikamba (35 ha) and *P. tecunumanii* at Yucul (140 ha) will also be certified.

2.2.4. Uses and users of forest reproductive material

Forest reproductive material is used for growing trees for numerous purposes, ranging from production of wood and non-wood products to provision of environmental services and restoration of forests for biodiversity conservation. The establishment of research trials has also promoted international collaboration on the collection and exchange of tree germplasm and subsequently increased the use of high-performing tree species and their provenances.

Private or state-owned companies are often considered as major users of tree germplasm while establishing tree plantations or reforesting logged natural forests through artificial regeneration. However, depending on countries and regions, small-holder farmers and private forest owners also plant considerable numbers of seedlings or sow seeds of trees. Large-scale nurseries producing tree seedlings are often managed by companies or state agencies but small-scale nurseries operated by farmers and local communities are often the main source of tree seedlings in rural areas, especially in areas where no commercial forestry is practiced.

The germplasm of fast-growing plantation tree species is often used more widely across countries and regions as compared to other tree species. For example, the global plantation area of *A. mangium* has grown from an estimated 150 000 ha in 1993 (Pinyopusarerk et al. 1993) to over 2.1 million ha in 2005 (FAO 2006b). Indonesia has the largest area with about 1.2 million ha in Sumatra and Kalimantan (Midgley and Beadle 2008). The species is mainly used for pulpwood, but it is also being increasingly used as a solid timber for furniture production in countries such as Indonesia, Malaysia and Vietnam, where the technology to utilize small piece sizes has advanced rapidly during the last decade. In the case of *A. crassicarpa*, approximately 40 000 ha had been planted in Sumatra by 2000 (Evans and Turnbull 2004) and it is now estimated that there are around 250 000 ha in Indonesia and 50 000 elsewhere in Southeast (S. Midgley, Salwood Asia Pacific, pers. comm. 2009). Eucalypts are also widely used across different regions. For some eucalypt species, such as *E. globulus*, the majority of new plantations are now established with seed from improvement programmes. There were about 670 000 ha of plantations of this species in Portugal in 2001, and about 450 000 ha in Australia in 2005 (Parsons et al. 2006). It also forms the largest component of Chile's circa 380 000 ha eucalypt area.

Seeds of the six Central American and Mexican pine species included in this report have been used primarily for the establishment of commercial plantations and research trials both internationally and locally. The majority of the seeds collected and sold for *P. caribaea, P. maximinoi* and *P. tecunumanii* are predominantly for international use in plantations. Seeds of *P. greggii* and *P. patula* are mainly for internal use in southern Africa. *P. oocarpa* seeds appear to have both local and international demand. It is estimated that 80 percent of commercial quantities of seeds collected in Mesoamerica over the last three decades were purchased by the private sector, the other 20 percent by government agencies[4].

Similar to the fast-growing plantation tree species, some tropical hardwood species, such as teak, have also been widely grown in plantations throughout the tropics. Teak is grown in at least 36 countries across the three tropical regions and it constitutes an estimated 75 percent of the world's high-quality tropical hardwood plantations (Bhat & Ma 2004). Seed supply is a factor limiting planting efforts and reducing the quality of the plantations, especially in countries where teak is grown as an introduced tree species.

2.3. Benefits of the use and movement of forest reproductive material

The transfer of forest reproductive material has the potential to bring considerable benefits, especially in those cases where the introduced germplasm is the only option for tree establishment (e.g. when environmental conditions are extreme and/or when no local tree germplasm is available) or when the introduced germplasm has superior performance. For example, for many countries access to seeds of the Central American and Mexican pines is their only hope to find well-adapted species and populations for marginal sites in the tropics and subtropics. The benefits of collecting, testing and transferring seeds of these pines and other tree species not only provide advantages to the private sector but also to local communities and farmers. In many countries in the tropics and subtropics, the responsibility for plantation establishment, maintenance and protection is being transferred to local communities which have an important stake in the management and success of the forestry operations.

Agroforestry systems provide multiple benefits for users and the environment. Small-scale farmers in the tropics rely on many different tree species to support their needs for timber, fruits, medicines, fodder and for improving soil fertility. Germplasm exchange can bring immediate returns to seed dealers, medium term gains for growers, and longer term societal gains through environmental conservation and management (Graudal & Lillesø 2007).

2.3.1. Food security and poverty alleviation

Trees growing both in production systems and in the wild have an important role in contributing to the food supply of rural communities in many parts of the world. Trees rarely provide a complete diet, but the supply of fruits, nuts and leaves is crucial to complement agricultural production, especially during drought, famine, disasters and conflicts. However, the potential of trees and forests to enhance food security and to fight malnutrition in developing countries is often neglected (Vinceti et al. 2008).

[4] In this estimate, it is assumed that PROFORCA program in Venezuela is a private sector not government organization.

In addition to food, trees and forests also provide many other non-wood products. For example, resin industries are common in parts of Brazil and Venezuela where pines like *P. caribaea* and *P. oocarpa* have been planted. Resin tapping operations are usually managed by small cooperatives owned by local communities. Resin tapping is also a common practice in natural pine forests of Central America, Mexico and Southeast Asia.

Growing trees also provides jobs and other income opportunities for people in local communities. In northern Mozambique, land that is not being used for crop cultivation has been leased from the local villages by a forestry organization for tree plantations. The forestry organization also hires villagers to plant, maintain, protect and, eventually, harvest the trees. The added income received by the villagers, who are subsistence farmers, provides a better standard of living for the community than what is earned otherwise. Currently, this particular forestry organization employs approximately 1000 local people in the communities. Furthermore, tree planting efforts generate income for small producers and farmers who sell seeds or seedlings to end users and tree seed centres.

2.3.2. Commercial benefits

The transfer of forest reproductive material from one country to another provides the recipient country with an opportunity to develop its forest resources. The transfer of forest reproductive material is commonly associated with the introduction of exotic tree species to new areas but often the material transferred is a better-performing provenance of a tree species naturally occurring in a given country. Furthermore, tree breeding efforts have made good progress in the case of several tree species and countries (and companies) are increasingly interested in obtaining improved germplasm for tree planting efforts to increase productivity. The increased productivity will not only benefit the owners of tree plantations but also other stakeholders, such as local processing facilities and manufactures using wood.

In the case of Mexican and Central American pines, for example, the value of plantation forestry in those countries where pines do not occur naturally is millions of dollars in annual revenues. Pine seed markets can also be lucrative in countries that possess natural stands, or for those in other regions that have established seed orchards. In Mesoamerica, villages sometimes form cooperatives to make seed collections in natural stands on their property and sell the seed to either national seed banks or international seed dealers. In some countries in Mesoamerica, the national seed banks have their own collectors. The cost of pine seeds of the six species presented in this report ranges from US$250 to US$400 per kg on the international market. Provenance testing of the six pines has strengthened these seed markets and helped to better target conservation efforts. Knowledge of what provenances are most productive has encouraged private landowners and national seed banks in Mesoamerica to give them a priority in their seed collection efforts.

Countries in Europe and North America rely mainly on native tree species for commercial forestry. However, forest reproductive material is transferred within and between the countries to increase productivity or enhance the adaptability of forests to given environmental conditions. The benefits of using high performance seed sources from outside the local area are often substantial.

2.3.3. Environmental benefits

The environmental benefits of transferring tree germplasm include soil protection and improvement, protection of water resources, regulation of microclimate and carbon sequestration. Several nitrogen-fixing tree species, such as *Acacia senegal* and *Erythrina abyssinica*, are well known for their contributions to soil improvement. Rapidly growing tree species have also been used for windbreaks, to stabilize river banks and to control erosion. Species like *P. caribaea, P. greggii, P. oocarpa*, and *P. tecunumanii* do well on degraded pasture lands and harsh soils on steep slopes in the tropics and subtropics. The 450,000 ha of Caribbean pine plantations established on the sandy plains of eastern Venezuela that are too dry for cultivated crops have created new industries (plantation forestry, resin tapping, sawmills, particle board mills etc.) where none existed before and improved the soil conditions. In China, the development of various protective forest systems since the 1950s has yielded environmental benefits resulting from the transfer of tree germplasm (Li et al. 1999).

There are also environmental risks linked to the introduction of forest reproductive material, such as the possible spreading of new invasive insects or diseases not detected by phytosanitary evaluations. In some cases, introduced tree species may become invasive in the new environment. Hybridization of introduced tree species with native related species also poses a risk for some genera. The environmental risks have been underestimated in the past and they may create additional threats to local biodiversity in some cases. However, awareness of the risks related to introduction of forest reproductive material is growing and practices to reduce these risks are being increasingly adopted.

2.3.4. Incentives for conservation of forest genetic resources

The testing and use of forest reproductive material have also provided significant incentives for the conservation of forest genetic resources. This is demonstrated by the results of many international provenance trials and other studies highlighting the importance of conservation of specific natural populations and, in some cases, the urgency of establishing *ex situ* tree populations.

In case of the six Central American and Mexican pine species included in this report, results from the international provenance trials have had a profound affect on the conservation of the genetic resources of these species. In addition, the continued concern of losing entire populations of the pines in Mesoamerica due to over-exploitation has also encouraged organizations in recipient countries to conserve *ex situ* specific populations of pines. Six South African members of the Camcore programme are now in the process of establishing special *ex situ* conservation areas that include material from each population sampled in Mesoamerica (Camcore Annual Report 2007). The *ex situ* conservation efforts also benefit the countries of origin, in case there is a need to repatriate material that has been lost from its original location.

There are also examples of tree species which have a very limited natural distribution and which have become commercially important species outside their natural range. This has increased the attention and efforts to conserve the remaining wild populations of such tree species. Monterey pine (*Pinus radiata*) is one of most famous example of such tree species. Within its natural range, *P. radiata* occurs only as five small populations in California and the species has never been widely used for forestry in North America. It was first introduced to Australia for ornamental plantings around 1857 (Wu et al. 2007) and more seed was imported by the botanic gardens in the 1860s and 70s. After about 1880, there were abundant seed crops of *P. radiata* in Australia and subsequently there was no need for further significant seed imports (Wu et al. 2007). Owing to its rapid growth, the species was first used in plantation forestry in the beginning of 1920s. Large scale planting of the species started in the 1950s and planting efforts have continued since then in Australia and also expanded into other countries, such as New Zealand.

Camden white gum (*Eucalyptus benthamii*) is another example of a tree species with a very restricted natural distribution. It only occurs on alluvial soils along a few river systems in New South Wales, Australia. The species is considered vulnerable to extinction and many trees in the remnant populations are in poor health. These populations have been severely depleted as a result of agricultural activities and flooding caused by construction of a dam. Outside its natural range, the species is favoured as a fast-growing plantation species in temperate regions of South America, where greater cold tolerance is required than that offered by other eucalypts, such as *E. grandis* and the *E. grandis* x *E. urophylla* hybrid.

2.3.5. Interdependence among countries

Planted forests account for about 7 percent of the global forest area (FAO 2006b) and it is likely that the area of planted forest will continue to increase in the future. During the past decade, the driving force behind tree planting efforts was the need to meet the increasing demand for wood and non-wood products, as well as to provide environmental services. More recently, tree plantations have also been established for sequestrating carbon and growing raw material for producing biofuels. It seems likely that reduction of emissions from deforestation and degradation (REDD) will be included in a new international agreement to tackle climate change after the present Kyoto Protocol expires. Although the ongoing REDD discussion emphasizes “avoided deforestation”, the new climate agreement may also include forest rehabilitation and restoration. In that case, it would create an additional demand for forest reproductive material in the future and possibly also increase the interdependence among countries with regards to tree germplasm.

Currently, many countries are self-sufficient in their production of forest reproductive material. However, there are several countries which still rely on imported seed in their tree planting efforts. Often the demand is high for seed of introduced tree species, but in some cases countries are also importing seed of native tree species from neighbouring countries. Some countries even outsource nursery production to other countries to reduce costs and then import seedlings back into their own territory.

In case of the Central American and Mexican pines, for example, many countries in other regions rely on pine seeds from Mesoamerica to establish new plantations. In the past, from the 1960s to the 1990s, many research seed collections were carried out and simple collaborative agreements were signed between national seed banks and international organizations. Commercial amounts of seed were also traded freely between producers in Mesoamerica and users in other countries. There is a need for a continued international collaboration to ensure access to genetic material of these and other tree species.

At the present time, seed orchards of most of the six pine species have been established in regions where the species are grown as exotics and seed demand for *P. patula* and *P. greggii* can now be met locally. However, *P. tecunumanii* and *P. maximinoi* have been found to be poor seed producers in areas outside of Mesoamerica (Dvorak and Lambeth 1993). The matter is further complicated by the graft incompatibility problem in *P. maximinoi* clonal orchards (Dvorak et al. 2000b). There will be a continued reliance on seeds from natural stands in Mesoamerica for *P. maximinoi* and *P. tecunumanii* for years to come to meet the need for expanding plantations and for companies and organizations changing tree species composition in their plantations. Development of *P. oocarpa* seed stands and orchards have lagged behind those of other species, possibly because *P. tecunumanii* grows more quickly when planted on similar sites as an exotic. Despite this, there is still world-wide demand for *P. oocarpa* seed, and organizations in Central America and Brazil continue to be major suppliers of seeds.

Climate change is likely to increase the interdependence among countries in the future as it may be necessary to introduce new tree species or new provenances of already existing tree species, depending on predicted changes in climate in different countries and regions. In this regard, the previously established species and provenance trials in different parts of the world are invaluable for analyzing the impacts of climate change on tree species and how they will perform under new climatic conditions. However, there are still gaps and uncertainties in the present understanding on how forest reproductive material should be transferred in the face of climate change.

2.3.6. Transfer of forest reproductive material to facilitate adaptation to climate change

The transfer of forest reproductive material and the introduction of new tree species are commonly based on matching site and climatic conditions between the source site of the material and the new site. The emphasis has primarily been in obtaining tree species and genetic material that are more productive, better adapted to cold, drought and diseases, and that have better wood or fruit quality than the existing species or genetic material. Now the additional challenge is to obtain forest reproductive material which can grow not only under the present climatic conditions but also withstand the predicted conditions after 50 to100 years.

Since historical times, trees have experienced drastic changes in climate. However, the predicted changes in climate are expected to take place relatively fast, i.e. within one tree generation, and now the major concern is how fast trees can respond to climate change (e.g. Kremer 2007). Like any other organisms, tree populations have three options to cope with climate change: 1) migrate to more favourable environments; 2) persist in the current location through inherent plasticity, which allows species to survive in a wide range of environments; or 3) adapt genetically over time and generations to new conditions in the current location (Aitken et al. 2008).

Results of provenance trials have shown that most tree species and their populations have a high level of phenotypic plasticity. The high level of plasticity is not necessarily linked to the diversity of environments in which a species currently occurs. For example, species like *P. patula* and *P. tecunumanii* exhibit greater plasticity than one would expect based on the environmental conditions in their current geographic ranges in Mesoamerica (Van Zonneveld et al. 2009). However, our knowledge of phenotypic plasticity is still limited and the long-term eco-physiological responses of tree populations to climate change are difficult to predict. Factors such as the coexistence of species with different plasticity levels add further complexity, and the role of phenomena such as epigenetics – in which environmentally induced carry-over effects are observed across generations – in acting as a buffer against change are largely unknown, but they potentially play an important role (Aitken et al. 2008; Skrøppa and Johnsen 2000). Furthermore, current models are unable to account effectively for different life history characteristics e.g. age to maturity, fecundity, and seed dispersal) and do not consider range fragmentation adequately, nor the differential adaptation present among populations that is so evident in tree species (Mimura and Aitken 2007).

Despite the high level of phenotypic plasticity and adaptive capacity of trees, transfer of forest reproductive material may be needed to facilitate adaptation of trees to climate change. Scientific debate on this issue is still continuing and it is difficult as yet to provide guidelines for transferring the material due to many uncertainties and unanswered scientific questions. However, possible transfer strategies or guidelines are likely to vary according to tree species and geographical region, increasing the demand for tree germplasm and the need for international collaboration.

In particular, for geographic regions with limited resources and capacities, such as small island countries in the Pacific, the supply and movement of tree germplasm should be considered as an important component of the national and regional adaptation strategies to climate change, and the rehabilitation of degraded forest lands, coastal and watershed protection and food security. However, in case of African agroforestry tree species, the international exchange of germplasm to combat climate change will mean little to smallholders unless improvements are made in the existing seed and seedling delivery systems that service them.

2.4. Conclusions

The exploration, assessment and movement of forest reproductive material have a long history in the forest sector. Early provenance trials revealed the existence of "geographical races" within tree species and also that the origin of the seed has a major influence on the performance of tree planting efforts. Numerous international provenance trials have been established for many tree species to test the performance of tree germplasm from different countries. Subsequently, the results of these provenance trials have had a large influence on the types of germplasm being transferred between countries and regions. The provenance trials have also provided incentives for conservation of forest genetic resources.

In the case of many tree species, the first introductions, and sometimes large-scale plantations, were based on a narrow genetic basis with forest reproductive material obtained from just one location or very few trees. In other cases, the introductions were done using forest reproductive material from multiple sources, which contributed to the development of landraces. Unfortunately, poor documentation of the multiple introductions complicates the tracing of provenance origins of the landraces. Efforts have been made to broaden the genetic basis of planted tree populations; these efforts must continue in order to maintain the adaptability, productivity and disease resistance in the face of climate change.

Seed remains the most common type of forest reproductive material. It is increasingly obtained from improved seed sources, but seed collection from wild stands, plantations and trees on farms still remains common practice. There is no clear pattern among different groups of tree species (i.e. fast-growing plantation tree species, tropical hardwoods, agroforestry tree species, and temperate and boreal tree species) in this regard; however, there are variations in the availability of seed among different countries and regions. Forest reproductive material is used for growing trees for numerous purposes and private or state-owned companies are often considered major users of tree germplasm. However, depending on countries and regions, smallholder farmers and private forest owners also plant considerable numbers of seedlings. Large-scale nurseries producing tree seedlings are often managed by companies or state agencies, but small-scale nurseries operated by farmers and local communities are often the main source of tree seedlings in rural areas.

The use and movement of forest reproductive material has yielded considerable benefits in many aspects. International cooperation reducing the associated costs and relatively easy access to germplasm has made it possible to test the material and increase its use. More recently, however, increasing difficulties [e.g. high costs, lack of access and misinterpretation of the Convention on Biological Diversity (CBD) provisions] have existed in moving forest reproductive material, especially for research purposes. This poses serious limitations to further testing and use of forest reproductive material. These difficulties are partly related to the fear that movement of material may contribute to the spreading of pests or diseases. While preventive measures are necessary to minimize this risk, they must be targeted in a manner which does not impede the movement of forest reproductive material. Moreover, while invasiveness also presents a potential risk, awareness is growing of how to effectively manage and prevent this.

The examples presented in this chapter lead to a general conclusion that there is a need to facilitate the use and movement of forest reproductive material to increase the associated benefits. The use and movement of forest reproductive material also increases the portfolio of options to maintain productivity in the face of climate change.

CHAPTER III: CURRENT PRACTICES OF MOVEMENT OF FOREST REPRODUCTIVE MATERIAL

3.1. Demand and supply

The current practices adopted for the movement of forest reproductive material vary across countries and regions. This chapter provides some examples and data on different groups of tree species as well as general considerations.

3.1.1. Fast-growing plantation tree species

In the case of acacias and eucalypts, commercial seed collectors in Australia have continued to make large-scale provenance bulk and individual-family collections from natural stands of those provenances which have been found to give superior plantation performance in international provenance trials. The Australian native seed collecting industry has an estimated sales value of AU$10 million per year. In recent years, land management agencies in several Australian states have increasingly restricted collections to reduce associated damage to vegetation in national parks, and to increase royalties from seed collection from other land categories.

There are well-developed international seed markets of most acacias and eucalypts included in this report, with the exception of *E. benthamii,* for which seed remains very scarce (but seed production capacity appears to be rapidly growing in South America). It is possible to buy seed of acacias and eucalypts from international seed merchants at very low cost (only a few US dollars per kg), but such seed lots have no pedigree information. This kind of seed is typically collected from plantations or even roadside trees with no attention to provenance pedigree, genetic quality of parent trees or flowering status of the stands. The performance of such seedlots is often very poor (Hai et al. 2008). Forest research agencies and private companies in many countries, such as Australia, Brazil and South Africa, market acacia and eucalypt seed that they certify to be produced in seed production areas or seed orchards comprising selected trees of know provenance origin. This kind of seed is much more expensive, but it has been shown to perform very well in variety trials (Hai et al. 2008).

Some tree breeding agencies in Brazil, China, India, South Africa and Thailand have developed acacia and eucalypt clones and they also market (or exchange) the clones within countries and/or internationally. These clones are typically supplied as micropropagated plantlets in tissue culture, which reduces quarantine risks. Clones may be sold outright for unrestricted use by the purchaser in some cases, or licensed for propagation with royalties payable on a permanent or per-hectare basis.

Until the late 1990s, the Australian Tree Seed Centre (ATSC) freely distributed seeds of acacias and eucalypts with no conditions attached to their use. Research seedlots were provided free of charge to research organizations and NGOs in developing countries through a series of development assistance projects supported by the Australian Government aid agencies (AusAID and ACIAR). Commercial companies were required to pay for seed at rates sufficient to cover the cost of collecting and maintaining the ATSC seed collections.

In 1997, ATSC introduced a memorandum of understanding (MoU) covering all seed despatches (Midgley 1999). The intention of the MoU was to ensure that the ATSC could access, on behalf of Australia and the international community, potentially important sources of germplasm in the future, in the event that access to the base populations in Australia be lost or depleted. The MoU has been widely recognized, with virtually no customers refusing to accept seed under its terms. To date, ATSC has not accessed any germplasm under the specific rights asserted by the MoU; this would probably only occur in the event of exceptional circumstances.

The issue of quarantine is a serious impediment to germplasm exchange of acacia and eucalypt species. Guava rust (*Puccinia psidii*) is a serious fungal disease of eucalypt*s* and other myrtaceous genera in many countries in Central and South America but not in Australia. For this reason, importing eucalypt material back into Australia from these places is only allowed under very strict conditions and in small quantities. Imported clones and seedlings germinated from imported seed must be held in a quarantine glasshouse for two years prior to inspection and release, if disease-free. Some commercial clones of *E. globulus* and eucalypt hybrids developed in South America are being tested in Australia, having been imported in tissue culture under these conditions. Guava rust also poses a threat to eucalypt plantations in other countries where it is not yet present. Molecular tests are now available for detecting the presence of the disease in reproductive material (Langrell et al. 2008).

Many countries have strict quarantine laws that prohibit, restrict or place conditions on the movement of forest reproductive material. Some of these laws (such as those aforementioned relating to guava rust) are obviously necessary and reasonable, in other cases phytosanitary requirements are arbitrary and unnecessarily restrictive. Export of acacia and eucalypt seed to Malaysia is impeded by phytosanitary declarations relevant to horticultural crops that are also applied to seed of eucalypts and acacias (the entire *region* where the seed was collected must be declared free from San Jose scale (*Quadraspidiotus perniciosus*) - a species that occurs neither on these genera nor on seed). In the Solomon Islands the seed must be declared and tested free of viruses (which cannot be done without killing the seed, therefore seed cannot be imported) and in Sri Lanka, both genera must be declared free of nematodes (some species of nematodes will be present in virtually all seed – seed must be boiled to kill them).

One consequence of excessively restrictive quarantine laws is the practice of illicit import and export of seed. ATSC is aware of numerous cases of seed being exported by private Australian seed collectors on behalf of overseas companies to transitional destinations, which have fewer import restrictions and will not control export declarations; the hand-carrying of seed through airports is another associated problem.

The Australian Quarantine Inspection Service (AQIS) collaborates closely with similar agencies around the world. AQIS ensures that Australian exporters do not export forest reproductive material unless they have complied with the regulations of the recipient country (typically a phytosanitary certificate, sometimes specific conditions and declarations or an import permit). Table 3.1 summarises some of the conditions on imports and exports of seed between Australia and major destination countries.

The demand and supply of pine seeds from Central America and Mexico have greatly fluctuated over the past 30 years. In Table 3.2, sales of seed (in kg) of the six pine species are shown over a five year period from 2004 to 2008. The data is obtained from the national seed banks in Honduras and Nicaragua (ESNACIFOR & BFS&CGM), a private seed dealer in Honduras and Brazil (SETRO and Schuckar), and private companies in South Africa with commercial seed distribution programmes (Mondi and Komatiland Forests (KLF). Seed sales are separated by whether they were local or international.

Enough pine seeds have been commercially sold (or transferred) by national seed banks, seed dealers and the forest industry over the five years to establish approximately 370,000 ha of plantations (the calculation assumes that seedling recovery rates in the nurseries are 50 percent and plantation spacing is 3 m x 3 m). These estimates are on the lower side because surveys have not been made for the entire seed industry. The demand and supply of the seeds varies by year, region and country, depending on rate of plantation establishment and change in seed capacity as new seed stands and seed orchards mature. Worldwide supply of *P. caribaea, P. greggii, P. oocarpa* and *P. patula* seems adequate, but the demand currently exceeds supply in case of the best provenances of *P. maximinoi* and *P. tecunumanii*.

3.1.2. Tropical hardwoods

Teak seed has a growing demand in the international markets, but improved or high quality seed is in low supply. There are also problems in distributing good quality seeds to planters of teak and other species (cf. Graudal & Lillesø 2007 and references herein). The problems include lack of awareness, lack of markets and an absence of funds to run national seed production programmes, as well as a long lag time between investments and gains and the involvement of numerous stakeholders in different parts of the seed production process under the national programmes (Graudal & Kjær 2001).

In the case of Central and South American hardwood species, the demand for seed export of *Swietenia macrophylla* and *Cedrela odorata* has grown considerably during the recent years in Costa Rica (see Figures 3.1 and 3.2). In Colombia, the seed demand for native tree species has also exceeded the demand for exotic tree species (Pinto 1996). According to information provided by the Tropical Seeds Company (SETRO), the most important native tree species in Honduras are *S. macrophylla, C. odorata, Swietenia humilis, Cordia alliodora* and *Leucaena leucocephala*. The export of seed of *S. macrophylla* was 700 kg in 2008, while the national demand was 300 kg. In the same year, a total of 120 kg seeds of *C. odorata* were collected, but only 7 kg were exported and 34 kg were used for distribution within the country.

Seed collection costs of tropical hardwood species are relatively high. Seeds of *S. macrophylla* and *C. odorata* were collected from all Mesoamerican countries for research purposes and the estimated price was US$ 700 per kg for *S. macrophylla* and *C. odorata* (with around 50 fruits per tree collected from more than 300 mother trees) (Navarro et al. 2003). However, the costs are much lower for bulk seeds, around US$ 100 per kg or even lower. According to Samaniego et al. (1996), the cost of collecting one kg of seed of *S. macrophylla* in grasslands, where trees are scattered, can be as low as US$ 34 per kg.

3.1.3. Agroforestry tree species

Current germplasm exchange practices by formal and informal actors in the smallholder agroforestry sector in East Africa are presented in the following paragraphs, with particular reference to the case of Kenya. Most research to characterize delivery systems has been undertaken in this country, where formal suppliers include the Kenya Forestry Seed Centre (KFSC) and the World Agroforestry Centre (ICRAF). Informal suppliers include private seed dealers, independent nursery operators and individual farmers that collect their own seed. Data on the actual volume of material passing through different categories of dealers and being received by nursery operators and farmers is fragmentary, and more research is needed.

KFSC, which is part of the Kenya Forestry Research Institute, is the most important national agency selling tree seed in Kenya (> 200 species indicated in its latest catalogue). A review of the 10 most demanded trees (by total seed weight) from KFSC in the 2007-2008 financial year (Table 3.3) indicates that only three species, *Cordia africana*, *Markhamia lutea* and *Vitex keniensis* (all timber species) are indigenous to Kenya, while the remainders are not found naturally in the African continent. This indicates a strong emphasis on introduced tree species, although all of the exotics of the top 10 most distributed taxa are now sourced locally from seed orchards or farmers' stands in Kenya, rather than internationally. Local sourcing of exotics raises the question of whether this material is of optimum performance based on current improvement initiatives elsewhere.

Volumes supplied to different clients from 2007 to 2008 are as follows (approximate values): 1 200 kg to the Kenyan Forestry Department for plantation establishment; 300 kg directly to national farmers and farmer groups; and 250 kg to NGOs operating in the country. Assuming that most seed provided to NGOs is eventually planted by smallholders, then approximately 30 percent by weight of seed of the 10 most demanded species was planted by farmers. Seed from some priority trees such as *E. grandis* was seen to be in high demand by all types of client.

ICRAF is part of the Consultative Group on International Agricultural Research (CGIAR) and it has a Genetic Resources Unit (GRU) that maintains a seed storage and distribution facility at its headquarters in Nairobi. The GRU is not a commercial supplier of seed but provides scientists across the tropics with small volumes of material for experimentation. On occasion, however, it also delivers larger amounts of germplasm for pilot development projects with a research component. A review of the 10 most distributed species from the GRU within Africa in the 2007-2008 year (Table 3.4) shows that most are exotic to the continent, with only two trees, *Markhamia lutea* and *Sesbania sesban*, being native to Kenya, and *Dovyalis caffra* occurring naturally only in southern Africa. The immediate source of all seed of the 10 taxa most distributed by the GRU was stands established in Kenya; germplasm was often of untested or poorly tested performance. Some of the most distributed species were the same as those distributed by KFSC, but with a stronger emphasis by the GRU on fodder trees. KFSC has a policy not to deal commercially in some of the species on ICRAF's most distributed list, because it takes the position that informal suppliers are better able to service demand (this applies for *C. calothyrsus* and *D. caffra*).

In previous years, the GRU has provided much more material internationally, as illustrated by transactions in *S. sesban* seed. Whereas in from 2007 to 2008 only 2 kg of seed were distributed by the GRU, in the years 1999 and 2000 a total of more than 2 000 kg of *S. sesban* seed were collected in Kenya and dispatched to north-eastern Zambia for a large pilot development project on soil fertility improvement (Jamnadass et al. 2005). Larger volumes were dispatched from Kenya to the same region in earlier years (Franzel et al. 2002; note that *S. sesban* is also native to the dispatch area, but Kenyan material was still chosen because it showed faster growth).

The GRU provides germplasm to researchers under the terms of the Standard Material Transfer Agreement of the International Treaty on Plant Genetic Resources for Food and Agriculture, and subject to the various national legislations of the countries concerned. Export and import to/from Kenya is regulated by the Kenya Plant Health Inspectorate Service (KEPHIS), where phytosanitary measures are based on international standards.

Muriuki (2005) reported that the top five species provided by local tree seed dealers operating at three locations in Kenya were all exotic, with *Grevillea robusta* being the tree species most dealt with (24 percent of dealers listed it among their top three species), followed by *Eucalyptus saligna* (20 percent), *D. caffra* (16 percent), *Cupressus lusitanica* (8 percent) and *C. calothyrsus* (6 percent). All of these trees are exotics to Africa except *D. caffra* (native to southern Africa, see above). Limited observations conducted on the physiological and genetic quality of supplied germplasm, which compared seed from private dealers with that from KFSC, seemed to refute conventional wisdom that informal dealers generally provide material of lower physiological quality than formal suppliers (although the range in quality of seed from different informal suppliers was high). Muriuki (2005) also observed that trained dealers tend to collect seeds from more trees during sampling, possibly because they recognise the importance of maintaining a wide genetic base during collection.

Regarding independent nursery operators, Muriuki (2005) found that the operators claimed to obtain 24 percent of the seed lots that they planted from informal private seed dealers. A larger proportion of the seed lots that they established (57 percent) came from their own collection activities ("self-collection"), while only 10 percent were obtained from government sources (KFSC, the Forestry Department and the Ministry of Agriculture). "Self-collection" was favoured because germination rates were generally perceived to be high, seed was "cost-free" and germplasm could be collected when it was required. Nursery operators indicated that seed supply was often insufficient to meet their clients' demands for seedlings of particular species. Constraints included a lack of finance to extend the scale of their activities in order to access further sources. Additional studies have identified current seed collection practices by informal nursery operators as a bottleneck in delivering genetically diverse germplasm to farmers (around a quarter of seed lots collected by nursery staff came from single trees only; Lengkeek et al. 2005a).

In the case of individual farmers, data collected on the origin of farm trees in the Meru region of Central Kenya indicate that, once farmers have established trees on their land, they tend to rely on these stands as sources of germplasm for future generations of planting. The reason given by farmers is that this is more convenient and cheaper than returning to external sources (Lengkeek et al. 2005b). Surveys of farmers' practices in other parts of Africa and elsewhere in the tropics have shown a similar pattern of behaviour (Brodie et al. 1997, Weber et al. 1997).

In reviewing tree germplasm availability in Central Kenya, Mbora and Lillesø (2007) concluded that patterns of exchange between formal and informal suppliers, and formal and informal sources, are complex. From the data presented above, however, it is clear that both formal suppliers and formal sources provide only a small part of the total tree seed that is exchanged in Kenya. This is in a country where the formal tree seed sector is relatively strong. In Africa as a whole, the majority of demand for tree seed and seedlings is either met through the informal sector or not met at all.

3.1.4. Temperate and boreal tree species

In North America, the supply of seed from seed orchards has outpaced demand for several major species and seed is collected locally from natural stands to meet specific needs. In Canada and the United States, each jurisdiction or region is largely self-sufficient with respect to seed supply for forestry purposes. In the United States, the demand for hardwood material, in particular, sometimes exceeds supply and state nurseries have been requested by the public to increase seedling production (Karrfalt, pers. comm.).

The markets for forest reproductive material function differently depending on the jurisdiction within Canada and the United States, and depending on whether material is handled by private or public dealers. The biggest producers of commercial forest seed in Canada and the United States are seed orchard managers (private and public) and the material they produce is for very specific users, usually forest industry operating within the particular breeding zone. Often, the forest industry and seed orchard owners are connected through co-op membership, joint ownership or some other arrangement. Little or none of this seed is put up for sale on the open market. Forest companies that run their own seed orchards generally do not sell seed. Small amounts of seed are exchanged for research purposes.

In some cases, private collectors sell seed internationally and to forest nurseries locally, especially if there is a shortfall in seed production by government or state nurseries. They do not generally have access to improved seed so the seed they collect and sell is from natural stands.

Some organizations have material transfer agreements (MTAs) for exchange of seed for research purposes. However, movement of reproductive material in North America has always occurred freely. Phytosanitary certificates are required to move material into Canada or the United States, and export permits are required describing the purpose, content, quantity and value of shipments. Any further documentation is voluntary.

Under the Seeds Act of the Canadian Food Inspection Agency of the Department of Agriculture and Agrifoods, regulations may be made to set standards, including purity, germination percentage and quality for any seeds imported or exported into or out of Canada. Currently, it is not applied to forest seed, but the act exists with provisions for forest tree seed if its application is deemed appropriate. There are restrictions on movement of a few endangered species, although most tree species that are listed nationally are not included in the CITES (Convention on International Trade in Endangered Species) list so it has little practical application.

In British Columbia, the provincial forest policy states that all seed used for forest planting must meet Chief Forester's "Standards for Seed Use", including registration, storage, selection and transfer. There are very specific rules regarding transfer of individual seed sources and special permission is required to allow forest seedlings to be planted outside of their zones. New standards are coming into effect in 2009, with transfer rules modified in response to expected changes in climate.

3.2. Conclusions

The demand and supply of forest reproductive material varies considerably over time, depending on the establishment of new plantations, seed crop, species and regions. In general, it seems that the supply of forest reproductive material is often insufficient to meet the demand, excluding most tree species in Europe and North America. In some cases, specific biological issues, such as the scarcity of seed production in the case of teak, considerably limit the availability of forest reproductive material, and especially of material of superior quality. In other cases, germplasm distribution problems represent the most significant factors in preventing the supply from meeting the demand of users, particularly for many agroforestry species. Furthermore, in many African countries, the formal supply of tree germplasm satisfies only a low proportion of current demand.

Large amounts of seed are moved through the trade sector and are typically not documented or certified. It is possible to buy seed from international seed merchants at low prices but without any pedigree information. Such seed is typically collected from easily accessed plantations and the use of the material often produces poor growth performances, though this is not always the case.

Collection costs have increased considerably compared to the past due to the amount of time which must be invested in the administrative procedures to comply with different regulations and conventions. Phytosanitary requirements, in particular, vary from country to country and for different types of material moved. Quarantine issues are a serious impediment to germplasm exchange of acacia and eucalypt species. Many countries have strict quarantine laws that prohibit, restrict or place conditions on the movement of forest reproductive materials. While certain laws (such as those related to guava rust) are clearly necessary and reasonable, other phytosanitary requirements are arbitrary and unnecessarily restrictive, sometimes leading to the illicit practices in the import and export of seed.

The movement of forest reproductive material may take place under various agreements (bilateral MTAs or MoUs); however, a standard MTA is not used (excluding the ICRAF collection of tree germplasm).

CHAPTER IV: POLICY FRAMEWORKS AND PERCEPTIONS OF STAKEHOLDERS ON THE MOVEMENT OF FOREST REPRODUCTIVE MATERIAL

4.1. Sector-specific policy initiatives on forest reproductive material

There are a number of international conventions and agreements that cover some aspects related to the conservation and use of forest genetic resources. However, only a few of them touch upon aspects related to the transfer of forest reproductive material and access and benefit sharing in the forest sector.

The Convention on Biological Diversity (CBD), adopted in 1992, affirms that states have sovereign rights over their biological and genetic resources, and that they are responsible for conserving their biological diversity and for using their biological resources in a sustainable manner. In 2002, the CBD adopted an expanded work programme on forest biological diversity. This programme makes specific reference to forest genetic resources and the integration of related concerns both in the conservation of biological diversity and in sustainable forest management. Thus the CBD is the most comprehensive legally-binding international agreement covering technical, regulatory and property-related aspects of forest genetic resources. The formal inclusion of forest genetic diversity in the work programme of the CBD, including the documentation and management requirements, provides an important vehicle for countries to further strengthen their efforts to manage forest genetic resources.

Although the CBD acknowledges that countries have sovereignty over their biological resources as a general principle, a number of regulations have been developed to address concerns over biosafety issues related to the movement of reproductive materials. More specifically, the Cartagena Protocol on Biosafety deals with the movement across boundaries of living modified organisms. To date, the protocol makes no particular reference to forest reproductive material or product.

The legally binding International Treaty on Plant Genetic Resources for Food and Agriculture (ITGRFA) came into force in 2004. In its present form, the ITGRFA covers the major crop and forage species, listed in Annex 1 of the Treaty. The only tree species with direct relevance to forestry in the multilateral system are members of the genus *Prosopis* (mesquite).

In the forest sector, there is no equivalent to the Global Plan of Action for the Conservation and Use of Plant Genetic Resources for Food and Agriculture, which focuses on agricultural crops. The Global Plan, adopted by the Fourth International Technical Conference on Plant Genetic Resources in Leipzig, Germany in June 1996, makes reference to wild relatives of cultivated plants, often found in forest ecosystems, and to domesticated tree crops, such as fruit trees and rubber, but it explicitly excludes forest tree genetic resources (FAO 1996a).

After UNCED (United Nations Conference on Environment and Development), the Intergovernmental Panel on Forests (IPF) (1995-1997), the Intergovernmental Forum on Forests (IFF) (1997-2000) and currently the United Nations Forum on Forests (UNFF) (since 2000) have been the main intergovernmental fora for international forest policy development. These have generated more than 270 proposals for action towards sustainable forest management, but the proposals have not included any significant action on forest genetic resources.

In 2007, the UNFF finally adopted a non-legally binding instrument (NLBI) on all types of forests to promote the implementation of sustainable forest management, including enhancing national action and international cooperation in this area. The NLBI has provisions on benefit-sharing relating to the use of traditional forest-related knowledge, but it does not refer specifically to forest genetic resources. The CBD and the UNFF are two separate schemes, but they both deal with forest biological diversity and sustainable forest management. Furthermore, there are potential synergies between the CBD work on access and benefit-sharing and the NLBI, which need to be further explored. The CBD and the UNFF should therefore collaborate more closely as the ongoing negotiation process to establish an international regime on access and benefit-sharing (ABS) that will inevitably have impact on both access and use of forest genetic resources, as well as the implementation of sustainable forest management.

4.2. Perceptions of users and providers on access to forest reproductive material

The concerns expressed by experts who contributed to the preparation of this report are not related to the lack of an international mechanism for access and benefit sharing of forest genetic resources. Instead, the most pressing concerns pertain to the increasing difficulty in obtaining and moving forest reproductive material across national borders for research purposes, which is partly due to actions taken to implement the CBD. In addition, difficulties in moving forest reproductive material are often associated with national and international rules for phytosanitary measures which vary from country to country and for different types of plant material. At the same time, commercial seed traders are able to trade large quantities of seed, often with limited documentation.

4.3. Examples of how forest reproductive material is addressed as part of the overall access and benefit-sharing (ABS) discussions at the national level or in legislation

The European Union is supportive of national legislation aimed at implementing Article 15 of the CBD and the Bonn Guidelines on Access and Benefit-sharing. Several European countries have revised their legislation to implement the Bonn Guidelines.

In May 2009, the Nordic countries launched a one-year project to analyze ABS issues and compare related national legislations (see Box 4.1). The project is coordinated by the Nordic Genetic Resources Centre (NordGen) and its objective is to determine the need for and possibility of taking legal steps to ensure that forest genetic resources remain under a viable public domain and open exchange system. The project is expected to describe the present situation with regards to access and rights in relation to forest genetic resources in the Nordic countries, present relevant cases in which there is a need to harmonize legislation (see box 4.1) with a general open exchange system (which is a desirable condition), and propose legal or policy interventions for decision-makers.

Box 4.1. ABS discussion on forest genetic resources (FGR) in the Nordic countries

A free exchange system for FGR is in place among Nordic countries which allows for the easy transfer of material, and consequently, unrestricted availability of seeds and breeding materials. However, there is growing concern that future developments may lead to an exclusive private right to access FGR, following the steps of other sectors, i.e., in crop genetic resources. Efforts to examine the current situation and to define the legal status of FGR have therefore been initiated.

Patenting is not applied extensively to FGR as in other sectors, such as animal breeding and fish farming. In Nordic countries this is also due to the timeframe of the patent protection (20 years) and the time needed to obtain benefits from timber harvesting with long rotation times (e.g., 50 to 100 years). However, the situation may change in future. There are possibilities that patents would cover breeding methods, with indirect effects in terms of product protection. It could also be that international efforts to harmonize patenting between different regions of the world (e.g. between EU and the United States) may have repercussion in the forestry sector.

Over the last decade, ICRAF and its partners in Africa have promoted the participatory tree domestication approach to better share the benefits at a local level and to make use of tree species that are important only at local and regional levels. The participatory method, in which smallholders are directly involved in local level selections of semi-, incipient or previously un-domesticated taxa in the landscapes that they inhabit, empowers local people and facilitates adoption (Akinnifesi et al. 2008). The process not only involves collection of germplasm, but the training of farmers in better ways to multiply and manage species, with an emphasis on vegetative propagation techniques for indigenous fruit trees to shorten the interval between planting and fruiting.

The participatory approach allows farmers to retain control over germplasm, since they themselves are directly involved in improvement, and their rights to material are thereby assured. Farmers can engage in seedling and seed exchanges with their neighbours under their own terms and receive mutual benefits, while wider germplasm transfers that involve significant planting elsewhere must be managed and protected by agencies that take account of farmer-breeders' rights. The costs involved in dealing with a potentially wide range of species are lower with the participatory approach than for centralised methods of improvement, and activities are more sustainable when farmers are directly involved (Leakey et al. 2007). However, decentralised methods for improvement mean that the scientists involved require different skills (in working directly with farming communities) than those of conventional breeders, and control of the research process is reduced. Existing research institutions frequently do not have the interdisciplinary, team-based structures needed to effectively undertake such work (Dawson et al. 2009)

The participatory domestication of tropical trees is most relevant when significant diversity is still available in the landscapes occupied by farmers (e.g., when agricultural land borders are still wild or in relatively unmanaged forest habitats). To assure germplasm availability under these conditions, policy interventions may be required to allow communities access to local forest, especially if trees occur within protected areas that are managed by government authorities. Allowing farmers to have "official" access to protected areas has the additional advantage of providing an incentive for their involvement in participatory forest management strategies that many countries in the tropics have recently attempted (with limited success) to promote (Wily 2003).

4.4. Conclusions

In the forest sector, no sector-specific initiatives on ABS issues related to tree germplasm presently exist. To date, the dialogue on ABS issues on forest genetic resources has been rather limited within countries; however, these issues are increasingly being considered following the example of the agricultural sector. Difficulties in moving forest reproductive material often rise from national and international rules regarding phytosanitary measures which differ from country to country and among types of plant material.

CHAPTER V: CONCLUDING REMARKS

The information and data collated for this report clearly indicate the need to initiate measures to facilitate the global movement of forest reproductive material. The transfer of this material has been a common practice for several centuries, and field trials established with introduced material have provided valuable insight on the performance of different tree species and their provenances. Results of field trials have directly influenced the transferring of and requests for germplasm and have given countries the opportunity to test new material. Nonetheless, increasing difficulties are being experienced in the movement of forest reproductive material for research purposes with regards to, the high collection costs, lack of access to the genetic resources and the misinterpretation of the CBD provisions. Large international efforts that have taken place in the past to systematically assess the performance of forest reproductive material would not be possible today due to such difficulties.

The appropriate use of forest reproductive material is a crucial part of forestry and agroforestry and forest development. However, the supply of forest reproductive material is often insufficient to meet the demand; this trend is expected to continue to increase in the future. The movement of forest reproductive material is sometimes based on a variety of agreements (bilateral MTAs or MoUs), yet no standard MTA is used (excluding the ICRAF collection of tree germplasm), and, in many cases, the movement of the material is poorly documented. Documentation associated with secondary transfer of germplasm, in particular, is crucial to maintain the identity of the material and to ensure its appropriate use. It has also been proposed that the use of high quality forest reproductive material should be actively promoted. The dialogue on ABS issues on forest genetic resources has, thus far, been rather limited within countries; however, these issues are increasingly being considered, following the example of the agricultural sector.

The use and movement of forest reproductive material of both exotic and native tree species brings considerable benefits and opportunities for improving the livelihoods of rural communities that depend on forest resources. However, it is often feared that movement of forest reproductive material may contribute to the spreading of pests or diseases. Preventive measures must be targeted in a manner which does not create barriers to the movement of the reproductive material. Furthermore, if potentially virulent diseases develop or are accidentally introduced into a region, one of the most effective ways to identify resistant trees is by field testing additional species and populations. This is not possible if the phytosanitary rules and regulations are too restrictive, preventing potentially valuable germplasm from being brought into a country. It is acknowledged that invasiveness is a potential risk and awareness on how to manage this risk is growing.

Transfer of forest reproductive material may be needed to facilitate adaptation of trees to climate change. Scientific debate on this issue is ongoing and guidelines for transferring forest reproductive material have not yet been formulated due to many uncertainties. Nonetheless, the use and movement of tree germplasm should be considered as an important component of the national and regional adaptation strategies to climate change. Furthermore, the gene pools of important tree species are rather narrow in certain countries and regions. In these instances, there is a need to broaden the gene pools to maintain the adaptability, productivity and disease resistance of the tree species.

Measures must be taken to address the current weaknesses of existing tree germplasm delivery systems at national and local levels. In many countries, interventions undertaken internationally to improve the exchange of forest reproductive material are likely to have only a limited impact on the material available for smallholders to plant. In developing countries, formal suppliers are able to provide only a small proportion of the material cultivated by smallholders and most farmers indicate lack of access to germplasm as a major constraint. There is a need to rethink the operational means by which tree germplasm reaches smallholders; innovation is required to reallocate roles among current actors to improve quality, capacity and information flows.

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APPENDIX I – FOREST REPRODUCTIVE MATERIAL MOVED INTERNATIONALLY

Table 1.1. The uses, natural distribution and major planting regions or countries of selected fast-growing plantation tree species.

Latin name	Common name	Uses	Natural distribution	Major planting regions/countries	Remarks
Acacia crassicarpa	Northern wattle	Pulpwood, timber, soil improvement	Western Papua New Guinea (PNG), the Papua Province of Indonesia, northern Queensland (Australia)	Asia, Africa, Central and South America, Oceania	
Acacia mangium	Mangium wattle	Timber, furniture, veneer, fodder, soil improvement	Eastern Indonesia, western PNG, northeast Queensland,	Asia, Africa, Central and South America, Oceania	
Eucalyptus benthamii	Camden white gum	Pulpwood, timber, charcoal	New South Wales (Australia)	Argentina, Chile, Uruguay, China, South Africa	Vulnerable to extinction in the wild
Eucalyptus camaldulensis	River red gum	Fuelwood, pulpwood, charcoal, timber, poles	Australia (tropical, Mediterranean and temperate climates)	Asia, Africa, America, Oceania, southern Europe	Good tolerance of drought, high temperature, periodic water logging, frost and soil salinity
Eucalyptus globulus	Tasmanian blue gum	Pulpwood, fuelwood, timber, charcoal	South-eastern Australia (including Tasmania)	Asia, Africa, America, Oceania, southern Europe	Planted in temperate and Mediterranean climates
Eucalyptus urophylla	Timor mountain gum	Pulpwood, fibreboard, fuelwood	Indonesia, Timor-Leste	Asia, Africa, America, the Caribbean, Oceania	Relatively resistance to pests and diseases
Pinus caribaea var. *hondurensis*	Caribbean pine	Timber, pulpwood, plywood, fuelwood	México, Belize, El Salvador, Guatemala, Honduras, Nicaragua	Australia, Brazil, Uganda, Venezuela	
Pinus greggii	Gregg's pine	Timber, pulpwood, plywood	México	Southern Africa, Central and South America	Good drought tolerance, two varieties (var. *greggii* and var. *australis*)
Pinus maximinoi	Thinleaf pine	Timber, pulpwood, plywood	México, El Salvador, Guatemala, Honduras, Nicaragua	Brazil, Colombia, eastern escarpment of Africa	
Pinus oocarpa	Mexican yellow pine	Timber, pulpwood	México, Belize, El Salvador, Guatemala, Honduras, Nicaragua	Brazil, Colombia, Central America	Good resistance to the Pitch canker fungus *(Fusarium circinatum).*
Pinus patula	Mexican weeping pine	Timber, furniture, veneer, plywood, pulpwood	México	Colombia, eastern escarpment of Africa	Two varieties (var. *patula* and var. *longipedunculata*)
Pinus tecunumanii	Tecun Umán pine	Timber, pulpwood	Southern México, Belize, El Salvador, Guatemala, Honduras, Nicaragua	Brazil, Colombia, eastern escarpment of Africa	Good resistance to the Pitch canker fungus (low-altitude populations)

Table 1.2. The uses, natural distribution and major planting regions or countries of selected tropical hardwoods.

Latin name	Common name	Main uses	Natural distribution	Major planting regions/countries	Remarks
Canarium indicum	Canarium nut	Nuts, canoes, timber, furniture	Eastern Indonesia, Papua New Guinea (PNG), Solomon Islands, Vanuatu	Countries within the natural distribution	Widely planted around villages and settlements
Cedrela odorata	Spanish cedar	Timber, furniture, veneer,	From Northern Mexico to Argentina	Central and South America, the Caribbean, Oceania, southern Africa, SE Asia	The aromatic wood is naturally termite and rot resistant
Endospermum medullosum	Whitewood	Timber, veneer, plywood, medicine	Eastern Indonesia, PNG, the Solomon and Santa Cruz Islands, Vanuatu	Countries within the natural distribution, Australia	The bark and leaves are used as medicine, including treatment of rheumatism
Santalum austrocaledonicum	Sandalwood	Oil, incense, carving, timber	New Caledonia, Vanuatu	New Caledonia, Vanuatu, Australia	Oil extracted from the heartwood is used for cosmetics, soaps, perfumery, aromatherapy and medicines
Santalum yasi	Sandalwood	Oil, incense, carving, timber	Fiji, Tonga	Fiji, Samoa, Tonga	Oil extracted from the heartwood is used for cosmetics, soaps, perfumery, aromatherapy and medicines
Swietenia macrophylla	Mahogany	Timber, furniture, veneer	Mexico, Central America, northern part of South America	Central and South America, the Caribbean, Asia, Oceania, West and East Africa	
Tectona grandis	Teak	Timber, furniture, veneer	India, Myanmar, Thailand, Laos, Indonesia (naturalized)	Asia, Africa, Central and South America, the Caribbean, Oceania	

Table 1.3. The uses, natural distribution and major planting regions or countries of selected agroforestry tree species.

Latin name	Common name	Uses	Natural distribution	Major planting regions/countries
Acacia senegal var. *senegal*	Gum acacia	Gum arabic, medicine, fodder, fuelwood, charcoal	The Sudano-Sahelian belt in Africa and from East Africa across Arabia to India and Pakistan	Kenya, Niger, Sudan, Senegal,
Artocarpus heterophyllus	Jackfruit	Fruit, soil improvement, fodder, fuelwood	India, SE Asia	India, Bangladesh, Myanmar, Sri Lanka, Malaysia, Indonesia, Thailand, the Philippines
Azadirachta indica	Neem	Medicine, pesticide, oil, fodder, timber, fuelwood	Afghanistan, Bangladesh, China, India, Myanmar, Pakistan, Sri Lanka, Thailand	Africa, Asia, Caribbean, Oceania, Central and South America
Casuarina equisetifolia	Casuarina	Timber	SE Asia, Melanesia, Polynesia	Asia, Africa, Central and South America, the Caribbean, Mexico, Oceania
Cordia africana	Large-leaved cordia	Timber, tool handles, musical instruments, fodder, charcoal	East and West Africa	Africa, Saudi Arabia, Yemen
Leucaena diversifolia	Wild tamarind	Fodder, soil improvement, poles, timber, fuelwood	Mexico, Guatemala	Asia, Africa, the Caribbean, Central and South America, Oceania
Mangifera indica	Mango	Fruit	South and SE Asia	Asia, Africa, Central and South America, the Caribbean, Oceania
Melia azedarach	Umbrella tree	Medicine, insecticide, oil, fodder, fuelwood	South and SE Asia, tropical China, Papua New Guinea (PNG), Salomon Islands, Australia	Widely planted across Africa, Asia, Middle East, the Pacific, Central and South America
Prunus africana	Red stinkwood	Medicine, poles, timber	West, East and Southern Africa	Several African countries
Sesbania sesban	Sesban	Fodder, soil amelioration, fuelwood	Africa	Asia, Africa, the Caribbean, South America, Oceania

Table 1.4. The uses, natural distribution and major planting regions or countries of selected temperate and boreal tree species.

Latin name	Common name	Uses	Natural distribution	Major planting regions/countries
Abies alba	Silver fir	Timber, pulpwood, plywood, furniture	Western, southern, central and eastern Europe	Several countries within the natural distribution, Ukraine
Abies grandis	Grant fir	Pulpwood, timber, Christmas tree	Western Canada and USA	Canada, USA, Austria, Czech Republic, France, Germany, UK
Fagus sylvatica	European beech	Furniture, pulpwood, veneer, plywood	Large parts of Central and Western Europe	Several countries with the natural distribution
Picea abies	Norway spruce	Timber, pulpwood	From the Alps and the Balkan Peninsular to Scandinavia and Siberia	Many countries in Europe, Canada, USA
Picea glauca	White spruce	Timber, pulpwood	Canada, USA	Canada, USA
Picea sitchensis	Sitka spruce	Timber, pulpwood, plywood, musical instruments	Pacific coast of Canada and USA (including Alaska)	Canada, USA, France, Germany, Norway, Iceland, Ireland, UK
Pinus contorta	Lodgepole pine	Timber, pulpwood	Pacific and Cordilleran regions of western North America	Denmark, France Germany, Ireland, Norway, Sweden, UK
Pinus sylvestris	Scots pine	Timber, pulpwood	From Spain and UK across the Eurasian continent to Russia	Nearly all countries within the natural distribution, Canada, USA
Pinus taeda	Loblolly pine	Timber, pulpwood, plywood, fuelwood	South-eastern USA	South-eastern USA, South Africa, Brazil, Australia, New Zealand, China
Populus nigra	Black poplar	Pulpwood, cardboard, packaging	From northern Africa across large part of Europe to Central Asia	Several countries within the natural distribution, China, USA
Pseudotsuga menziesii	Douglas-fir	Timber, pulpwood	Western North America	Canada, USA, France, Germany, UK, New Zealand
Quercus robur	Pedunculate oak	Timber, furniture, veneer	From western Europe and southern Scandinavia to Russia and Turkey	Most countries with the natural distribution, Canada, USA
Quercus rubra	Red oak	Timber, furniture, veneer	Eastern Canada and USA	Canada, USA, Belgium, France, Germany, Hungary, The Netherlands

Table 2.1. Regional summary of ATSC dispatch records for *Acacia mangium* from 1980-2009. P= provenance collection of five seedlots (provenance bulks) or more; I= individual family lots, shaded cells include dispatches with a significant proportion of genetically improved seedlots.

Region	1960-65	1965-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2001-05	2006-10
Australasia	-	-	-	-	P	4P6I	6P8I	P4I	3P2I	6PI
Pacific	-	-	-	-	5P	3P2I	P	P	-	-
South America	-	-	-	-	2P	P	P	I	P	-
Central America	-	-	-	-	14P	4P	4P	5P	-	-
S.E. Asia	-	!	-	-	22P	29P7I	39P13I	18P2OI	8P7I	6P4I
S. Asia	-	-	-	-	5P	6P	3P	3P2I	-	-
Asia	-	-	-	-	4P	4PI	-	2PI	P	I
Africa	-	-	-	-	15P	7PI	2P	P	P	-
Europe/N. America*	-	-	-	-	4P	7PI	2P	-	P	P

*These were almost certainly re-exported to other countries

! Initial introduction of seed collected from one mother tree to Sabah, Malaysia by D.I. Nicholson

Table 2.2. Regional summary of ATSC dispatch records of *Eucalyptus globulus* from 1981-2009. P= provenance collection of five seedlots (provenance bulks) or more; I= individual family lots.

Region	1960-65	1965-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2001-05	2006-10
Australasia	-	-	-	-	5P	15P13I	9P6I4*	8P5I	2P	P5I
Pacific	-	-	-	-	-	-	P	-	-	-
South America	-	-	-	-	4P	2PI	2P4I	P	I	-
Central America	-	-	-	-	3P	P	PI	-	-	I
S.E. Asia	-	-	-	-	P	2P2I	2P2I	-	-	2PI
S. Asia	-	-	-	-	4P	3PI	P	P	-	-
Asia	-	-	-	-	3P	2P2I	5P	3PI	P2I	2I
Africa	-	-	-	-	2P	5P2I	PI	2PI	I	I
Europe	-	-	-	-	6P	6P6I	6P4I	4PI	4I	I

* Four individual collections dispatched to Australian seed brokers are likely to have been exported subsequently

Table 2.3. Regional summary of ATSC dispatch records of *Eucalyptus camaldulensis* from 1981-2009. P= provenance collection of five seedlots (provenance bulks) or more; I= individual family lots, shaded cells include dispatches with a significant proportion of genetically improved seedlots.

Region	1960-65	1965-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-00	2001-05	2006-10
Australasia	-	-	-	I	13P	22P4I	9P3I	10P11I	5P10I	P3I
Pacific	-	-	-	-	2P	-	-	P	-	-
South America	-	-	-	-	16P	3PI	5P	3PI	PI	-
Central America	-	-	-	-	3P	4P	PI	PI	I	P
SE Asia	-	-	-	-	21P	22PI	17P3I	9P2I	3P7I	4P3I
S. Asia	-	-	-	-	33P	19PI	11P3I	4P8I	P3I	I
Asia	-	-	-	-	7P	11P2I	3PI	7P3I	2P2I	4PI
Africa	-	-	-	-	14P	13PI	4P	PI	3P	-
Europe/N America	-	-	-	-	8P	2P	3PI	PI	-	-
Mediterranean/Middle East	-	-	-	-	3P	P	I	I	-	2PI

Table 2.4. Origin and plantation area of six important Mesoamerican pines

Species	**Country of Origin**	**Major Planting Regions**	**Estimated Plantation Area (ha)**	**Reference**
P. caribaea var. *hondurensis*	Mexico, Belize, El Salvador, Guatemala, Honduras, Nicaragua	Australia, Brazil, Uganda, Venezuela	800,000	Dvorak et al. 2000c (*)
P. greggii	Mexico	South Africa	10,000	Camcore unpublished data
P. maximinoi	Mexico, El Salvador Guatemala, Honduras, Nicaragua	Brazil, Colombia, Eastern escarpment of Africa	10,000	Camcore unpublished data
P. oocarpa	Mexico, Belize, El Salvador, Guatemala, Honduras, Nicaragua	Brazil, Colombia, Central America	100,000	Camcore unpublished data
P. patula	Mexico	Colombia, Eastern escarpment of Africa	1,000,000	Kanzler 1994, Birks & Barnes 1991
P. tecunumanii	Mexico, El Salvador Guatemala, Honduras, Nicaragua	Brazil, Colombia, Eastern escarpment of Africa	10,000	Camcore unpublished data

(*) Dvorak et al. (2000c) cite the establishment of 1.0 million ha of Caribbean pine plantations ,but because of recent reduction in planting programmes and fires, primarily in eastern Venezuela, over the last 8 years, the figure has been reduced to 0.8 million ha.

Table 2.5. List of the most important native species exchanged by the BLSF in 2008 and the quantities exported. FI: Identified source; FS: Selected source; HS: Seed orchard; Export: Exported seed; National: National exchange(CR)..

Type of exchange	Species	Quantity exchanged(Kg)	Source	Viable seeds/kg	Total of seeds
Export	*Cedrela odorata*	**150.200**	FI	63653	9560680.6
National	*Cedrela odorata*	**11.406**	FI	63653	726026.118
Export	*Swietenia macrophylla*	**272.010**	FS	2141	582373.41
National	*Swietenia macrophylla*	**43.150**	FS	2141	92384.15
National	*Cordia allidora*	**3.313**	FI-HS	59145	195947.385
Export	*Cordia allidora*	**3.100**	FI-HS	59145	183349.5
National	*Enterolobuim cyclocarpum*	**6.150**	FI	1455	8948.25
Export	*Enterolobuim cyclocarpum*	**23.000**	FI	1455	33465
National	*Samanea saman*	**5.800**	FI	4627	26836.6
Export	*Astronium graveolens*	**2.850**	FI	28865	82265.25
National	*Astronium graveolens*	**0.300**	FI	28865	8659.5
Export	*Dalbergia retusa*	**8.250**	FI	3722	30706.5
National	*Dalbergia retusa*	**15.984**	FI	3722	59492.448
National	*Albizia guachapele*	**1.350**	FI	28885	38994.75
National	*Schizolobium parahybum*	**27.776**	FI	1131	31414.656
Export	*Tabebuia rosea*	**6.000**	FI	36335	218010
National	*Tabebuia rosea*	**4.070**	FI	36335	147883.45
National	*Tabebuia ochracea*	**1.580**	FI	48450	76551
Export	*Tabebuia impetiginosa*	**3.000**	FI	10226	30678
National	*Tabebuia impetiginosa*	**0.527**	FI	10226	5389.102

Table 2.6 A range of tree species important for smallholders in agroforestry practice that represent four different categories of tree use. Species were included in searches of ICRAF's Agroforestree Database (AFTD) and Tree Seed Suppliers Directory (TSSD).

Timber	**Medicine**	**Fruit**	**Fodder/soil fertility**
Adenanthera pavonina	*Acacia mellifera*	*Aegle marmelos*	*Acacia angustissima*
Afzelia quanzensis	*Acacia nilotica*	*Annona senegalensis*	*Acrocarpus fraxinifolius*
Bischofia javanica	*Acacia senegal*	*Annona squamosa*	*Alnus acuminata*
Brachylaena huillensis	*Albizia gummifera*	*Areca catechu*	*Antiaris toxicaria*
Casuarina equisetifolia	*Antiaris toxicaria*	*Artocarpus heterophyllus*	*Bridelia micrantha*
Casuarina junghuhniana	*Azadirachta indica*	*Averrhoa carambola*	*Calliandra calothyrsus*
Combretum molle	*Balanites aegyptiaca*	*Azanza garckeana*	*Chamaecytisus palmensis*
Cordia africana	*Caesalpinia spinosa*	*Bactris gasipaes*	*Crotalaria juncea*
Cupressus lusitanica	*Commiphora africana*	*Carica papaya*	*Croton macrostachyus*
Eucalyptus camaldulensis	*Cordia sinensis*	*Carissa edulis*	*Faidherbia albida*
Eucalyptus grandis	*Croton macrostachyus*	*Casimiroa edulis*	*Ficus sycomorus*
Eucalyptus saligna	*Dalbergia melanoxylon*	*Citrus sinensis*	*Flemingia macrophylla*
Gmelina arborea	*Erythrina abyssinica*	*Dovyalis caffra*	*Gliricidia sepium*
Grevillea robusta	*Eucalyptus citriodora*	*Eriobotrya japonica*	*Leucaena collinsii*
Hagenia abyssinica	*Flacourtia indica*	*Garcinia mangostana*	*Leucaena diversifolia*
Juniperus procera	*Ginkgo biloba*	*Grewia bicolor*	*Leucaena leucocephala*
Khaya nyasica	*Melia azedarach*	*Inga edulis*	*Mimosa scabrella*
Maesopsis eminii	*Moringa oleifera*	*Litchi chinensis*	*Morus alba*
Markhamia lutea	*Olea europaea*	*Mangifera indica*	*Polyscias kikuyuensis*
Melia volkensii	*Parkia biglobosa*	*Parinari curatellifolia*	*Rhus natalensis*
Milicia excelsa	*Piliostigma thonningii*	*Persea americana*	*Senna siamea*
Newtonia buchananii	*Prunus africana*	*Pouteria sapota*	*Senna spectabilis*
Ocotea usambarensis	*Salvadora persica*	*Psidium guajava*	*Sesbania macrantha*
Pinus patula	*Securidaca longepedunculata*	*Punica granatum*	*Sesbania rostrata*
Podocarpus falcatus	*Senna didymobotrya*	*Sclerocarya birrea*	*Sesbania sesban*
Shorea robusta	*Syzygium guineense*	*Syzygium cuminii*	*Tephrosia candida*
Spathodea campanulata	*Terminalia brownii*	*Tamarindus indica*	*Tephrosia vogelii*
Tectona grandis	*Warburgia ugandensis*	*Uapaca kirkiana*	*Terminalia catappa*
Trichilia emetica	*Ximenia americana*	*Vangueria infausta*	*Tipuana tipu*
Vitex keniensis	*Ziziphus mucronata*	*Ziziphus mauritiana*	*Trema orientalis*

Table 2.7 Summary of Agroforestree Database (AFTD) and Tree Seed Suppliers Directory (TSSD) searches by category of smallholder tree use. Thirty tree species represent each category (see Table 2.6).

Category of smallholder use	**Number of countries where tree is recorded as exotic** (1)	**Proportion of total range where tree is recorded as exotic, as % of all countries where found** (1)	**Number of suppliers of germplasm** (number of countries in brackets) (2)	**Number of suppliers of germplasm in native range** (2)	**Number of suppliers of germplasm not in native range** ('third party' suppliers in brackets) (2, 3)	**Proportion of suppliers providing research quantities only, as % of suppliers** (2, 4)	**Propagation methods for species** (5)
Timber	14	64%	16 (8)	6	10 (6)	8%	28S, 19V, 8W
Medicine	18	59%	10 (6)	4	6 (3)	14%	29S, 19V, 7W
Fruit	25	74%	8 (4)	2	6 (2)	11%	29S, 25V, 2W
Fodder and/or soil fertility	25	70%	11 (6)	4	7 (4)	12%	29S, 14V, 4W
Average across category of use (6)	21	67%	11 (6)	4	7 (4)	11%	-

(1) Average values across species (rounded to the nearest whole number), based on the subset of searches in the AFTD for which information on both the native and exotic distribution of a taxon is given (20, 16, 25 and 23 species for timber, medicine, fruit, and fodder and/or soil fertility use categories, respectively).

(2) Average values across species (rounded to the nearest whole number) based on searches of the TSSD; all 30 taxa for each use category included in calculations.

(3) 'Third party' suppliers are those located in countries where, according to the AFTD, a particular species is not found naturally or cultivated.

(4) Research quantities defined as < 1000 propagules, proportion based on the subset of searches in the TSSD where information on quantities is provided by suppliers.

(5) Occurrences in the AFTD where seed (S), clonal/vegetative methods (V) and wilding (W) transplantation are mentioned as means of propagating species. Many of the 30 species surveyed for each use category are propagated by more than one method.

(6) Arithmetic mean (rounded to the nearest whole number).

Database searches undertaken during the compilation of this report by Alexious Nzisa, ICRAF

Table 2.8 Summary of Agroforestree Database (AFTD) searches by category of smallholder tree use: species with the greatest exotic distribution according to the database (taken from 30 tree species representing each category).

Category of smallholder use	The five species with the highest number of countries using them as exotics	Number of countries
Timber	*Casuarina equisetifolia*	57
	Tectona grandis	35
	Eucalyptus camaldulensis	28
	Eucalyptus saligna	28
	Pinus patula	26
Medicine	*Azadirachta indica*	87
	Melia azedarach	50
	Moringa oleifera	36
	Acacia nilotica (subsp. *nilotica*)	27
	Eucalyptus citriodora	26
Fruit	*Mangifera indica*	65
	Artocarpus heterophyllus	62
	Persea americana	58
	Carica papaya	54
	Eriobotrya japonica	49
Fodder and/or soil fertility	*Leucaena diversifolia*	81
	Sesbania sesban	66
	Gliricidia sepium	63
	Flemingia macrophylla	49
	Tephrosia candida	46

Database searches undertaken during the compilation of this report by Alexious Nzisa, ICRAF

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APPENDIX II - SOURCES OF FOREST REPRODUCTIVE MATERIAL

Table 2.9 *Acacia mangium* collections

Year	Material collected	Range of collection	Reference and notes
1979-80	17 provenances, 149 families (AU); 2 provenances 133 families (PNG)	North Queensland, AU and Morehead and Bensbach Rivers, PNG	Doran and Skelton (1982)
1988	12 provenances, 161 families	Western Province, PNG	Gunn, McDonald *et al.* (1988)
1988	5 provenances, 30 families	North Queensland (AU)	(Gunn, McDonald *et al.* 1988)
1990-1991	14 provenances, 92 families (Queensland); 2 provenances 28 individuals (PNG)	North Queensland, AU; Lake Murray, PNG (northern extent of range in PNG)	House, Larmour *et al.* (1991); Vercoe and McDonald (1991)
1993	Unknown	Muting-Bupul, Papua Province, Indonesia (formerly known as Irian Jaya)	Faculty of Forestry Gadjah Mada University (E. Hardyanto pers. comm. 2009)

Table 2.10 *Acacia crassicarpa* collections

Year	Material collected	Range of collection	Notes
1988	9 provenances, 69 families	Western Province, PNG	Gunn, McDonald *et al.* (1988)
1991	3 provenances, 34 individuals	North Queensland	House, Larmour *et al.* (1991)
1993	8 provenances, 108 families	Western Province, PNG between Bensbach and Oriomo Rivers.	Gunn (1994)
1993	Unknown	Muting-Bupul, Papua	Faculty of Forestry Gadjah Mada University (E. Hardyanto pers. comm. 2009)

Table 2.11 *Eucalyptus camaldulensis* collections

Year	Material collected	Range of collection	Notes
1964	30 provenances	Wide-ranging	Prov. Trials were established in 24 sites in 10 countries
1972	25 provenances	South Australia, Central Australia, Northern Australia	Turnbull (1973b) Jointly sponsored by Forestry & Timber Bureau and FAO
1973	13 provenances	Gulf of Carpentaria (Queensland)	Collected jointly by CTFT and FRI[1](Turnbull 1974)
1977	3 provenances, 77 families	Collections for genetic conservation at Petford and Gibb R. (Queensland) and Katherine (Northern Territory)	Doran and Boland (1978)
1985	4 provenances, 178 families	Petford region (Queensland)	Doran (1985)
1975-present	340 provenances	Entire range – numerous trips	ATSC records, see also Butcher, McDonald *et al.* (2009)

1. The FRI Seed Section later became the CSIRO Australian Tree Seed Centre

Table 2.12 *Eucalyptus benthamii* collections

Year	Material collected	Range of collection	Reference and notes
1984	10 families	Wentworth Falls	ATSC records
1987	3 families	Bents Basin	ATSC records
1993	2 populations, 49 families	Bents Basin, Kedumba Valley	Larmour (1993)
1995	4 populations, 28 families	Range-wide	Gardiner and Larmour (1995)
2003-2008	198 families, all derivative of previous collections	From pedigreed seed orchards and population-pedigreed seed stands	ATSC records

Table 2.13 *Eucalyptus globulus* collections

Year	Material collected	Range of collection	Notes
1978	20 provenances	Tasmania, some of other *E. globulus* ssp. from Victoria and NSW	Provenance trials were established in Tasmania, with excess seed made available to others (Orme 1978)
1987, 1988	616 families, 49 localities	Across most of natural range including some intergrade zones with other subspecies of *E. globulus*	Jordan, Potts *et al.* (1993)
1993	15 provenances, 137 families	Tasmania and Victoria, Australia	Gardiner (1994)

Table 2.14. Summary of Camcore provenance/mother collections and establishment of field trials for six Mesoamerican species from 1980 to2008, their current highest level of genetic improvement in breeding programs in the world (Camcore or non- Camcore) and levels of genetic diversity in regional or range-wide population assessments reported by various authors.

Species	No. of provenances sampled in Mesoamerica	No. of research field trials	Country location of field trials	Maximum level of improvement	Genetic diversity assessment: marker type/results
Pinus caribaea	34	114	Brazil, Venezuela,	3rd generation	Electrophoresis/high diversity (Dvorak et al. 2005)
Pinus greggii	16	98	Argentina, Brazil, Chile, Colombia, México, South Africa, Zimbabwe,	1st generation	Electrophoresis/moderate to very low diversity (Ramírez-Herrera et al. 1997)
Pinus maximinoi	26	87	Argentina, Brazil, Chile, Colombia, Guatemala, Mozambique, South Africa, Uruguay Zimbabwe, Venezuela	Beginning 2nd generation	Electrophoresis & RAPD/ average to below average diversity (Dvorak et al. 2002)
Pinus oocarpa	39	37	Brazil, Colombia, South Africa, Venezuela	1st generation	Microsatellites/average to above average (Dvorak et al. 2009)
Pinus patula	25	115	Brazil, Chile, Colombia, México, South Africa, Zimbabwe	2nd generation	Electrophoresis & microsatellites /average diversity (Butterfield 1990; Dvorak et al. 2009)
Pinus tecunumanii	54	181	Argentina, Brazil, Colombia, Chile, Mozambique, Uruguay Venezuela, South Africa	Beginning 2nd generation	Electrophoresis,RAPD & microsatellite/average to above average (Furman & Dvorak 2005, Dvorak et al. 1999, 2009)

Table 2.15 The main temperate and boreal tree species selected for the study with number of seedlings/cuttings planted yearly in Canada by province, species and source.

Province/ Territory	**# Seedlings/ Cuttings planted**	**Main Species**	**Source**
British Columbia	230 million	*Pinus contorta*, *Picea* spp, *Pseudotsuga menziesii*, *Thuja plicata,*(first 4 account for 90%, in that order); *Pinus monticola*, *Larix occidentalis, Tsuga heterophylla,*	50% Seed orchards: public, forestry companies, private; 50% wild stands
Alberta	130 million	*Picea glauca*, *mariana*, *Pinus banksiana, contorta*	Seed orchards and natural stand collection: forestry companies
Saskatchewan	34 million	*Picea glauca, mariana, Pinus banksiana*	Private seedling nurseries
Manitoba	15 million	*Pinus banksiana, resinosa, Picea mariana, glauca*	Natural stand collections, seed orchards: co-ops, public
Ontario	150 million	*Picea glauca* & *mariana, Pinus banksiana, strobus &resinosa*	Seed orchards: forestry companies, co-op
Quebec	150 million	*Picea mariana, glauca, Pinus banksiana*	Seed orchards: public
New Brunswick	40 million	*Picea mariana, glauca, Pinus banksiana*	Seed orchards: forestry companies, public
Nova Scotia	20 million	*Picea rubens, glauca* & *mariana*	Seed orchards: forestry companies, public
Prince Edward Island	1 million	*Picea rubens, glauca, mariana; Pinus strobus, resinosa; Larix laricina, Abies balsamea*	Seed orchards and collection from natural stands: public
Newfoundland & Labrador	9 million	*Picea mariana* & *glauca Pinus banksiana* & *strobus*	Seed orchards and natural stand collections: public
Yukon	100,000	*Picea glauca*	Natural stand collections: public
Total	**779 million**		

APPENDIX III – ISSUES LINKED TO THE COMMERCIAL MOVEMENT OF FOREST REPRODUCTIVE MATERIAL

Table 3.1. Table of quarantine conditions (prevailing in early 2009) for acacia and eucalypt species being exported from and imported to Australia. Shaded cells indicate conditions that either severely restrict or prohibit FGR exchange.

	Exports		Imports	
Country	*Acacia*	*Eucalyptus*	*Acacia*	*Eucalyptus*
Brazil, Uruguay and other S. American countries where guava rust is present	Brazil: Phyto and IP required – often the IP is very difficult and time consuming to arrange	Brazil: Phyto and IP required – often the IP is very difficult and time consuming to arrange	**A. mangium specific**: Phyto required; No IP required	Phyto & IP required; max. 100 seedlings per seed line, has to be grown in quarantine approved post-entry quarantine facility, seed from screened plants can be released after up to 12 months.
Hong Kong	Phyto required, though this usually has few difficult conditions	Phyto required, though this usually has few difficult conditions	As above	As above
China	Phyto and IP required	Phyto and IP required. Phyto requirements can be highly variable.	As above	As above
Malaysia	*A. mangium* specific: phyto and IP required: dusting of fungi insecticide. Other *Acacia* sp: Phyto, IP & AD required: CO2 + dusting.	**Specific to E grandis:** Phyto, IP & AD req. AD frequently not possible. **Specific to Eucalyptus spp**: Phyto, IP & AD + CO_2 + dusting.	As above	As above
Indonesia	Phyto required; IP required	Phyto required; IP required; often other bureaucratic requirements that are difficult to meet	As above + Khapra	As above + Khapra
South Africa	Phyto required.	Specific to Eucalyptus. Phyto & AD. Importation of the following species is prohibited*: E. camal; clado; diversicolor; lehmsnnii; paniculata; sideroxylon*	As above	As above
Pacific Islands	**Solomons:** Phyto, IP; dusting for lots of 250g. AD required - seeds to be tested and declared free of virus. **Tonga**: Phyto, IP. **Samoa:** Phyto, IP. **Samoa***:* *A. auriculoformis* - Phyto only.	**Solomons**: Phyto, IP; dusting for lots of 250g. AD required - 'Seed samples have been tested and have been found to be free of virus'. **Tonga:** Phyto, IP Samoa: Phyto, IP. **Samoa:** A. auriculoformis - Phyto only.	As above	As above
Sri Lanka	**A. mangium specific**: Phyto, IP and AD: seed tested and free from nematodes and insects.	**Eucalyptus specific**: Phyto, IP and AD: seed certified free from nematodes and injurious insects.	As above	As above

Phyto: phytosanitary certificate (usually with specific statements about pests and diseases); IP: import permit; AD: additional declaration; CO2: fumigation with carbon dioxide gas; Dusting: fungicide/insecticide treatment; Khapra: Considered a country from which Khapra beetle (*Trogoderma granarium)* may come - special conditions required to be noted on phyto and IP applies.

Table 3.2. Trends in local (L) and international (I) seed demand of the six pine species between 2004 and 2008 (see text for details).

Organization	**Species**	**2004**		**2005**		**2006**		**2007**		**2008**	
		L	I	L	I	L	I	L	I	L	I
ESNACIFOR	*caribaea*	18	6	54	46	82	59	84	70	39	315
SETRO	*caribaea*	2	109	2	132	3	9	4	129	14	222
CMG&BSF	*caribaea*	0	0	0	0	0	0	4	0	5	5
Schuckar	*caribaea*	359	89	280	229	440	1000	240	502	176	675
KLF	*caribaea*	**36	1	**24	11	0	0	0	12	12	0
Total		**415**	**205**	**360**	**418**	**525**	**1068**	**332**	**713**	**246**	**1217**
ESNACIFOR	*maximinoi*	7	75	34	179	22	139	8	54	3	108
SETRO	*maximinoi*	1	30	3	7	3	210	20	7	1	25
CMG&BSF	*maximinoi*	0	0	0	0	0	0	0	0	0	0
Schuckar	*maximinoi*	0	0	0	0	*50	0	0	0	0	0
Total		**8**	**105**	**37**	**186**	**25**	**349**	**28**	**61**	**4**	**133**
ESNACIFOR	*oocarpa*	39	0	49	728	107	57	225	68	239	29
SETRO	*oocarpa*	13	3	13	3	26	6	47	3	35	20
CMG&BSF	*oocarpa*	0	0	0	0	0	0	5	0	8	0
Schuckar	*oocarpa*	133	0	103	5	174	100	2	0	32	350

Total		**185**	**3**	**165**	**736**	**307**	**163**	**279**	**71**	**314**	**399**
ESNACIFOR	*tecunumanii*	6	1	2	8	6	6	1	10	0	0
SETRO	*tecunumanii*	0	56	1	27	0	35	1	50	0	16
CMG&BSF	*tecunumanii*	0	0	0	0	0	0	2	18	2	25
Schuckar	*tecunumanii*	0	0	5	5	0	2	73	0	0	143
Total		**6**	**57**	**8**	**40**	**6**	**43**	**77**	**78**	**2**	**184**
Mondi	*patula*	159	0	155	5	136	12	392	0	286	0
KLF	*patula*	131	2	309	14	282	53	203	12	323	5
Total		**290**	**2**	**364**	**19**	**418**	**65**	**592**	**12**	**609**	**5**
Mondi	*greggii*	4	0	60	0	53	0	29	0	28	0
KLF	*greggii*	7	0	0	0	0	0	0	0	0	0
Total		**11**	**0**	**60**	**0**	**53**	**0**	**29**	**0**	**28**	**0**

*Seed purchased from Honduras for resale in Brazil. Amount not counted in final tally.

** Seeds sold locally but most likely resold internationally.

Figure 3.1. Seeds exchanged at national level and exportation from the Latin American Seed Bank at CATIE for *S.macrophylla*. Information provided by the Latin American Seed Bank.

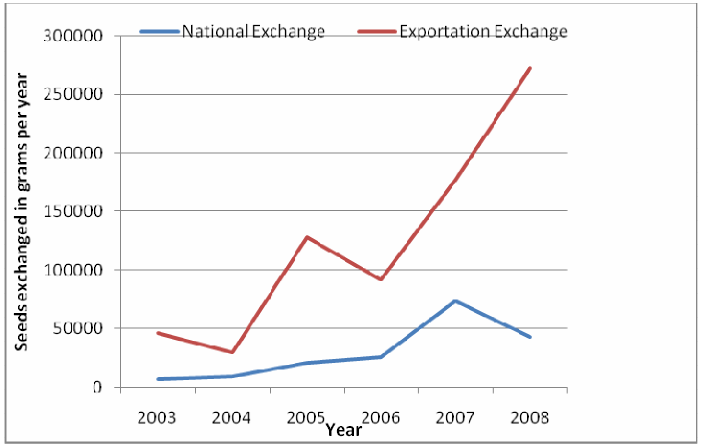

Figure 3.2 Seeds exchanged at the national level and exportation in the Latin American Seed Bank at CATIE for *C.odorata*. Information provided by Latin American Seed Bank.

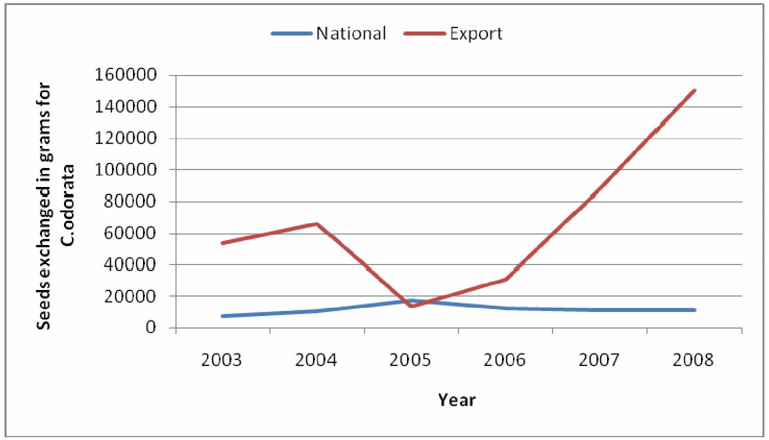

Table 3.3 The top 10 most demanded species from the Kenya Forest Seed Centre (KFSC), ranked by the volume supplied to different clients, 2007-2008.

All clients (Kg)	**Forestry Department** (Kg)	**Farmers and farmer groups** (Kg)	**NGOs** (Kg)	**Other institutions** (Kg)
Eucalyptus grandis (600)	*E. grandis* (300)	*E. grandis* (100)	*E. grandis* (100)	*E. grandis* (100)
Vitex keniensis (350)	*V. keniensis* (300)	*C. lusitanica* (100)	*P. patula* (50)	*V. keniensis* (20)
Cupressus lusitanica (300)	*C. lusitanica* (200)	*L. trichandra* (40)	*C. equisetifolia* (50)	*C. lusitanica* (0)
Pinus patula (220)	*P. patula* (150)	*V. keniensis* (30)	*C. junghuhniana* (50)	*P. patula* (0)
Casuarina equisetifolia (150)	*C. equisetifolia* (100)	*P. patula* (20)	*V. keniensis* (0)	*C. equisetifolia* (0)
Casuarina junghuhniana (100)	*C. africana* (100)	*L. leucocephala* (20)	*C. lusitanica* (0)	*C. junghuhniana* (0)
Cordia africana (100)	*C. junghuhniana* (50)	*C. equisetifolia* (0)	*C. africana* (0)	*C. africana* (0)
Leucaena trichandra (40)	*M. lutea* (30)	*C. junghuhniana* (0)	*L. trichandra* (0)	*L. trichandra* (0)
Markhamia lutea (30)	*L. trichandra* (0)	*C. africana* (0)	*M. lutea* (0)	*M. lutea* (0)
Leucaena leucocephala (20)	*L. leucocephala (0)*	*M. lutea (0)*	*L. leucocephala (0)*	*L. leucocephala (0)*

0 = not supplied in any significant volume to that client. Data provided during the compilation of this report by Peter Angaine, KFSC.

Table 3.4 The top 10 most supplied species from the ICRAF Genetic Resources Unit (GRU) in Nairobi, 2007-2008.

Species (ranked by volume)	**Total supplied** (Kg)	**Source of seed*** (origin)	**Countries seed supplied to** (major recipients)	**Purpose**
Calliandra calothyrsus	350	Farm stands, Busia	Malawi	Pilot development
Leucaena trichandra	200	Seed orchard, Muguga (Guatemala)	Malawi	Pilot development
Leucaena diversifolia	190	Seed orchard, Muguga (Mexico)	Malawi	Pilot development
Dovyalis caffra	100	Farm stands, Muguga	Zimbabwe	Pilot development
Moringa oleifera	11	Seed orchard, Mbololo	Cameroon, Kenya, Rwanda	Research
Tephrosia candida	10	Farm stands, Maseno	Rwanda	Research
Jatropha curcas	4	Farm stands, Kajiado	Kenya	Research
Macadamia tetraphylla	3	Farm stands, Embu	Cameroon	Research
Sesbania sesban	2	Seed orchards, Muguga (Kenya, Malawi)	Kenya, Mali, Zambia	Research
Markhamia lutea	2	Farm stands, Busia (Kenya)	Cameroon, Kenya	Research

The immediate source of all seed was Kenya, either from farm stands or seed orchards. The locations of stands are given. When the initial source of material is well documented, the country of origin is given in brackets. Data provided during the compilation of this report by Lucy Mwaura, ICRAF.

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