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Situational analysis of commercial and community tree planting in Southern Africa

TRENDS IN TREE IMPROVEMENT AND TREE GERMPLASM SUPPLY

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Crispen T. Marunda

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African Forest Forum
United Nations Avenue, Gigiri.
P.O. Box 30677-00100, Nairobi, Kenya
Tel: +254 20 722 4203
Fax: +254 20 722 4001
E-mail:exec.sec@afforum.org

Website: www.afforum.org.
Twitter @ africanff.
Facebook / African Forest Forum.
LinkedIn / African Forest Forum (AFF).

Author: Crispen T. Marunda

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Cover photos (L-R): A tree nursery (credit: C. Marunda); Demonstration plots of various Eucalypt species near Lichinga. *E. urograndis* and *E. pellita* (credit: C. Marunda); Pods of a multi-purpose tree species being dried in the sun at Chitedze Research Station, Malawi. (credit: C. Marunda).

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Acronyms/Abbreviation

AFF	African Forest Forum
AGM	Annual General Meeting
CBO	Community Based Organisation
CEF	Centro Experimentacao Florestal
CIDA	Canadian International Development Agency
DAFF	Department of Agriculture, Forestry and Fisheries
DFSC	Danida Forest Seed Centre
ETFRN	European Tropical Forestry Research Network
FRC	Forest Research Centre
GDP	Gross Domestic Product
DNFFB	National Directorate for Forestry and Wildlife
ICRAF	World Agroforestry Centre (nternational Centre for Research in Agroforestry)
IIAM	Instituto de Investigação Agrária de Moçambique
ISTA	International Seed Testing Association
FAO	Food and Agriculture Organization
FD	Forest Department
FRA	Forest Resource Assessment
FRC	Forest Research Centre
FRIM	Forest Research Institute of Malawi
IIBC	International Insitute of Biological Control
JMFRS	John Meikles Forest Research Station
LRC	Land Resources Centre
MMAI	Maximum Mean Annual Increment
MPTS	Multipurpose Tree Species
MTA	Material Transfer Agreements
NDP	National Development Plan
NGO	Non-Governmental Organization
NTSC	National Tree Seed Centre
R&D	Research and Development
RDP	Reconstruction and Development Programme
RSA	Republic of South Africa
SAA	Sustainable Afforestation Association
SADC	Southern African Development Community
SFM	Sustainable Forest Management
Sida	Swedish International Development Agency
TAFORI	Tanzania Forest Research Institute
TIMB	Tobacco Marketing Industry Board
TPF	Timber Producers' Federation
TOF	Trees outside forests

TSCN	Tree Seed Centre Network
TUP	Temporarily Unplanted Areas
USAID	United States Agency for International Development
ZAFFICO	Zambia Forestry and Forest Industry Corporation
ZIMASSET	Zimbabwe Agenda for Sustained Socio-Economic Transformation
ZNCC	Zimbabwe National Chamber of Commerce

1. Executive summary

The review is part of the African Forest Forum (AFF) project on Sustainable Forest Management (SFM) in Africa supported by the Swedish International Development Agency (SIDA). It addresses SFM in the context of tree planting for both industrial forests and community tree planting activities, and pays particular attention to the role of tree breeding and seed supply in increasing productivity and achieving SFM of planted trees in Africa. The approach to the review involved first understanding afforestation and reforestation activities, identifying the main tree species planted and related research and development (R&D) and tree seed production and supply activities. A gap analysis based on qualitative (policy trends) and limited quantitative data revealed a growing backlog of tree planting that would need more investments in R&D, with a greater focus on tree breeding and improved seed supply in southern Africa.

Visits to Malawi, Mozambique, South Africa, Zambia and Zimbabwe have invariably pointed to the fact that tree planting programmes are facing challenges, and rates of tree planting are declining due to diminishing land resources, illegal settlements, insecure tenure, land-use conflicts, increasing incidences of diseases and pests, diminishing investment in tree breeding and restrictive access to germplasm of good quality. There are projections of deficits in long-rotation timber, particularly for saw-logs, meaning that plantation development programmes in the future have to adjust to meet this deficit, and could result in increased demand for tree germplasm.

The commonly planted species for commercial forestry in the region are pines, eucalypts and wattle. There is a network of species and provenance trials that has provided valuable information on tree species' performance and products. Over the years, however, there has been a decline in basic forest research due to diminishing investments and development, policy shifts and institutional reforms. A number of research trials have been harvested as they had reached maturity (or mistakenly harvested) and there were no forward selections for next generation seed orchards as a source of improved germplasm. Most countries, except South Africa, reported the decline in productivity of seed orchards due to old age, lack of infusion of new genetic material, fire outbreaks and vandalism.

South Africa has nearly 75 % of its commercial plantations established with clonal and hybrid materials, whereas other countries are still using seed as the main source of propagation material. Clones have the potential to deliver more genetic gain than deployment of seeds, but clonal propagation is labour and capital intensive and the costs to produce plants is much higher compared to raising seedlings. Malawi, Mozambique and Zambia have imported untested seeds for establishing plantations with variable performance outcomes. New afforestation programmes in northern Mozambique have imported pine seeds from Chile, Uruguay, Colombia and Brazil, and eucalypts from Australia. Zimbabwe still depends on seed from its old seed orchards, but there are reports of declining productivity in them. Other pine species that have shown potential include *Pinus tecunumanii* and *P. maximinoi,* but are shy seed producers and meeting the demand for seed for these two species is going to be a challenge. There are also signs that Mozambique and South Africa are depending too much on clonal hybrids, especially *Eucalyptus grandis* x *urophylla* hybrids, and have neglected the traditional breeding programmes running the risk of narrowing the genetic base.

The widely planted eucalypt species, such as *E. grandis, E, camaldulensis* and *E tereticornis,* are being attacked by new pests, e.g. the blue gum chalcid (*Leptocybe invasa*) and red gum lerp psyllid (*Glycapsis brimblecombei*) causing extensive stem deformation, twig die-back, and tree mortality. In Zimbabwe and South Africa, these pests are a real threat to hardwood plantations and there are calls to introduce new species or resistant seed sources as part of an integrated pest management strategy that also includes biological control of the pests.

Planting rates of trees in the southern African region in the future are likely to depend not only on plantation and community woodlots and trees outside forests, but to a large extent on the emerging markets for environmental services. The combination of environmental service payments together with commercial returns from timber make it financially attractive and ultimately contribute to SFM. This will lead to an expansion of planting rates and will increase demand for new species and improved planting materials. Green Resources Ltd. in Mozambique, for example, has developed its business model around this concept and works in partnership with communities.

All the countries visited received substantial support to establish seed centres during the period from 1992 to 2000 through the SADC Tree Seed Centre Network funded by the Canadian International Development Agency (CIDA). Due to sectoral reforms, some countries had their seed centres moved to agricultural institutions or privatised (e.g. Mozambique and South Africa, respectively) and have become unconnected to the tree planting activities, especially for small-holder tree growers. Seed centres in other countries have suffered from low levels of investments resulting in not meeting demand of seed (e.g. Zimbabwe, Zambia and Malawi). Seed testing is done on an *ad-hoc* basis with adoption of a few International Seed Testing Association (ISTA) standards, especially for commercially important species.

The region has a wide range of provenances of pine, eucalypt, acacia and many other MPTS that have been assembled through government-funded R&D, international NGOs and private importations with support from institutions such as Camcore. However, the forestry sector needs to be aware of international processes that may restrict movement of genetic material, e.g. the Nagoya Protocol on access to genetic resources and Material Transfer Agreements between countries. There is a growing tendency in some countries—at a global level—Materials Transfer Agreements (MTS) not to allow their genetic material to be used by others, which may have implications at the regional level as the countries all depend on exotic species for most of their tree planting activities.

Apart from South Africa, where there is still a good level of investment in plantation management, all other countries reported a declining quality of plantations and end products. For example, in Zimbabwe, due to lack of investment and expertise, some companies are rehabilitating felled areas through managing pine wildlings. Coppice productivity of eucalypt plantations has gone down as the material is old and there has been no rejuvenation through the planting of improved/advanced regeneration for many decades.

The use of good quality tree germplasm is a critical success factor in any tree planting programme. Tree breeding and use of good germplasm increases productivity, wood quality and lowers wood production costs. Consequently, this generates increased profits, sustainable production of goods and services and ultimately sustainable management of planted forests. Efficient supply of good germplasm is more pertinent now in many parts of Africa where availability of land for large scale forestry plantation is limited requiring the need for increasing productivity per unit area. If the plantation growing stock is to be improved, significant attention needs to be paid to its genetic constitution. This entails careful management through a clearly defined tree improvement strategy that determines species adaptation and performance in a given environment. Understanding and developing forest genetic resources (FGR) using a species approach is a useful option. Given the high number of forest species present in each of the Southern African countries, it is impossible to develop research activities or programmes for all forest species. Priority species should be identified at national and subnational levels, and these priorities should be shared in existing regional and international fora so as to provide better focus and more efficient resource use. Some activities advocated for include;

- promoting research networks focusing on important species at national, regional and international levels,
- update priority species lists regularly at both country and regional levels,
- provide support for the development of guidelines for species prioritization and for the identification of priority areas of research,
- exchange of research seed-lots and sharing of research information and outputs, and,
- prioritization of indigenous species focusing on species, populations or varieties that are in danger of extinction, or on species of diverse current and future value.

The status for non-commercial species is not very clear. Collection of indigenous tree seeds is on an *ad-hoc* basis without clearly defined objectives apart from the need for conservation and planting for aesthetics. Malawi reported wide exchanges of agroforestry tree seeds between small-holder farmers and NGOs. Pathways from species trials, seed multiplication, quality control and delivery were not clearly defined for all countries. This area of research in agroforestry for small-scale farmers has been largely driven by donor funding. The dependence of these systems on donors or government subsidies has distorted the tree seed supply systems. There are many and varied end-users of the germplasm, and it is difficult for R&D to improve

MPTS and supply accredited seed as the priorities in terms of products and services keep shifting.

The participation of small-scale growers in plantation establishment in out-grower schemes brought with it new challenges such as access to good quality tree germplasm. New models of germplasm distribution that allows better access by the small-scale grower need to be developed. The challenges include geographical dispersion of the growers, variable sites and un-coordinated demand phases. This requires high levels of control and regulation by centralised authorities to ensure quality and good germplasm distribution networks.

There are increasing threats to forests and tree species from climate change, new diseases and pests. The challenge for SFM in Africa is to be as competitive as possible, and that means a continuous focus on increasing forest productivity through genetics, silviculture and forest health for both plantations and community forests. The different custodians of tree genetic material in the region have a unique resource, and through policy and regional programmatic support, there are opportunities to share the information and materials to improve performance of planted trees and plantations and achieve SFM.

2. Context and approach of the study

The study is part of a project that the African Forest Forum implemented under the project entitled "Strengthening Sustainable Forest Management in Africa" that sought to generate and share knowledge and information through partnerships in ways that provided inputs into policy options and capacity building in the forest sector. The ultimate goal was to better address poverty eradication and environmental protection in Africa through improved forest management (AFF, 2014). The project was funded by the Swedish International Development Agency (Sida).

AFF identified tree breeding and seed supply as key components of SFM and commissioned this study to review the status of tree breeding and germplasm supply in three geographical regions of Africa, *viz.* Central/West Africa, East Africa and Southern Africa. The overarching goal of the study was to contribute towards sustainable management of both plantation forests and trees planted for agroforestry as part of the project on Sustainable Forest Management in Africa. The study reviewed tree seed production and deployment systems for both commercial forestry plantations and general plantings by communities with a special focus on the Southern African Region.

The study, inter alia, looked at key elements of improving tree performance and productivity of both commercial and non-commercial tree species planted in different parts of Africa. The specific objective of the study was to understand the status of tree improvement and tree seed supply in the southern African region, and promote the use of better adapted and high quality germplasm. To get a good grasp of the status on the ground, the report reviewed plantation statistics in each of the countries in the region to get a picture of the afforestation and reforestation rates, policy issues affecting future tree planting activities, species used, tree breeding activities and seed production activities for the most important species (Figure 1). The study approach was based on the premise that the transition from deforestation (unsustainable forest management) to reforestation will create a strong demand for tree germplasm. Afforestation activities drive the demand for seed and good seed is a product of concerted and sustained efforts in tree improvement and breeding.

Figure 1. Interrelations amongst tree planting activities, tree breeding and seed systems.

The approach to the study was divided into several components as follows:

- Literature review to highlight SFM issues as they relate to commercial and community tree planting activities;
- Review literature on species introductions, provenance testing, and conservation of key species;
- Discussions on policies that are effecting afforestation and reforestation rates with forestry experts and leaders in the region, and plantation statistics are presented;
- Visits to selected countries to understand the levels of tree planting for both commercial and non-commercial species, afforestation and reforestation rates, gaps in planting activities, policies impacting on tree planting, and, hence, demand on R&D; and,
- Visits to seed centres and sending out questionnaires to gather information on seed production activities and constraints.

Five countries were visited: Malawi, Mozambique, South Africa, Zambia and Zimbabwe. They were chosen on the basis of the extent of their forestry plantations and tree planting activities by small-scale farmers. The countries were used as proxies for the SADC region. The trends in each individual country may be unique, but does give a good indicator of the situation in the region. For countries not visited, i.e. Angola, Namibia, Botswana, Lesotho, Madagascar and Swaziland, telephone interviews were conducted with key people in the forest sector, and further information was obtained from literature searches.

3. Structure of the report

The report is structured to give a brief review of SFM and how tree planting activities (plantation statistics and community tree growing activities) contribute to SFM goals in each of the countries. This is followed by a discussion on current policies affecting afforestation and reforestation rates, and discussion on tree breeding of the key species and the seed supply situation for commercial, indigenous fruit trees, agroforestry species and those species threatened by over exploitation. It is important here to emphasise that investments in tree breeding and seed supply needs to be coupled by rates of tree planting, hence this report dwells quite intensively on the plantation and tree planting policies and statistics (species x area) in the countries visited. The report recommends policies and strategies that can be employed by the individual countries and regional collaborative frameworks.

4. Limitations of the study

There is generally a paucity of information about current rates of harvesting and reforestation or afforestation rates in all the countries. Most private companies treated this information as commercial-in-confidence. Hence, most of the information was from discussions with forestry experts and was very qualitative rather than quantitative. For example, estimates of seed demand were not based on quantitative data.

The scope and time of the study was rather short to allow visits to all Southern African countries. Information on countries that were not visited was obtained from telephone interviews and literature reviews. The period of the visits did not allow for a detailed analysis of the status of species trials and seed orchards.

5. Planted forests and trees in Southern Africa

Planted trees, both at commercial and community levels, are invaluable resources that contribute to national economic development and meet the daily livelihood needs of people. Timber plantations offer attractive total returns from a combination of cash yield from timber sales and capital appreciation from biological growth. Forest resources in southern Africa are also recognised and valued for their provision of wood, food, building materials, and services such as watershed protection, wildlife habitat and carbon sequestration. They are also valued for their diverse ecosystems, unique biodiversity (plants, animals and landscapes) and for their cultural heritage. The total planted forests in Sub-Saharan Africa exceed 16 million ha and this area is projected to increase in the future (FAO, 2015). Reliable and up-to-date information on the state of forest resources is crucial in supporting decision making for investments and policy. This is particularly important when countries need to decide on investments in SFM programmes that have tree planting components.

There are c. 3 million ha of plantation forests, or approximately 1% of total forest cover, in the region (FAO, 2015). Table 1 shows plantation statistics and deforestation rates in the southern African countries. The data also shows that most countries have a negative net change in forest areas, suggesting that most countries in the region need to invest more to achieve SFM. Over 75% of the plantations are commercially managed, mostly privately owned in South Africa. The main commercial trees are *Pinus* and *Eucalyptus spp*., and few areas are under Wattle *(Acacia mearnsii)*. Short rotation forestry with eucalypts and pines (for pulpwood) has the support of high quality research, technology adoption mechanisms and decades of experience, especially in South Africa (Morris, 2008; Titshall et al., 2013). The plantation areas are usually located in areas of high elevation and high rainfall. Countries identified by FAO as most suitable for further commercial afforestation are Mozambique, Zambia, Angola and Tanzania.

Apart from the large scale plantations, there are numerous small scale woodlots, mainly established by rural communities and farmers using eucalypts grown and harvested for poles, firewood, building materials and fencing posts. Rural communities also plant agroforestry trees around their homesteads, field boundaries and grazing area to meet demand for wood and other domestic products. These trees are commonly referred to as trees outside forests (TOF). The extent of TOF plantings is difficult to estimate in terms of numbers and areas planted. Most of the economics related to these TOF is not easily captured in household or national economic statistics but their local importance is well documented.

The forests are subjected to a range of pressures, e.g. unsustainable harvesting practices, diminishing land for afforestation, uncertain tenure systems, increasing harvesting levels, climate change, pest and diseases, drought and fires. The sustainable management of forests in Southern Africa, whether on public or private land, require a sound understanding of their condition, use, management and how to increase productivity. In all countries in the region, governments, private forest companies and society in general recognise the need to complement natural forest productivity with the growing of trees in plantation and in community woodlots using fast growing species, usually of exotic origin.

Table 1. Forest statistics for countries in the Southern Africa region (adapted from FAO, 2015).

Country	Forest cover (1000 ha)	Percentage cover	2010 De-forestation (1000 ha/y)	2010 Af-forestation (1000 ha/y)	2010 Re-forestation (1000 ha/y)	2015 Plantations (1000 ha)	2015 Net change
Angola	57 856	46.4		0		125	-0.1
Botswana	10 840	19.1		0			-0.9
Lesotho	49	1.6		0.2		17	0.8
Madagascar	12 473	21.4	57	11.4	28	312	-0.4
Malawi	3 147	33.4	18	18.0	3	419	-0.9
Mauritius	39	19.2		0	0.1	18	-0.3
Mozambique	37 940	48.2	219	12.0	0	75	-0.5
Namibia	6 919	8.4		0			-0.9
South Africa	9 241	7.9		2.2	50.6	1 763	0
Swaziland	586	34.1		0		135	0.9
Zambia	48 635	65.4	287	0	1.5	87	-0.3
Zimbabwe	14 062	36.4	309	0	6	6	-1.8

Blanks denote very small number rounded off to zero.

Source: FAO, 2015.

The art of growing trees is underpinned by forest research that covers a broad spectrum of disciplines, including tree breeding and improvement, seed production and distribution, silviculture and protection against pests and diseases. The application of good scientific knowledge is essential for supporting SFM, and investments in research, particularly tree breeding and seed supply, will ensure the establishment of tree stands that have optimal growth, produce expected products and ensure a continues stream of knowledge during the growth of the trees and subsequent rotations. In Zimbabwe, for example, first generation selection of *P. patula* material in progeny trials resulted in 17 % genetic gain in volume compared to wild material with subsequent cumulative gains of 30 % and 45 % in second and third generation selections respectively (Barnes, 1993).

5.1 SUSTAINABLE FOREST MANAGEMENT

Sustainable Forest Management (SFM) is primarily a systematic approach to sustaining all the components of the forest ecosystem and the interaction amongst them. SFM has been defined by FAO (2005), as "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfil, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems." The growing of trees in plantations and in community tree planting projects has been viewed as one way of contributing towards achieving SFM and most African countries have recognised this as a long term objective and it is included as part of national and regional development plans and strategies (Kowero, 2009).

The implementation of SFM in Africa is hampered by the low priority given to the sector by central governments - poor enforcement of regulations, lack of incentives (particularly for local communities and the private sector), poorly-defined property rights, and the treatment of forests as open access resources. Some of the challenges or constraints include limited economic resources and infrastructure, low levels of technology, poor access to information and knowledge, inefficient institutions, and limited empowerment and access to resources (Chamshama et al., 2009). These factors are further compounded by corruption, poor forest policies, lack of relevant research output, especially in the public forest sectors, and lack of political will and support (Chamshama and Nwonwu, 2004; Chamshama et al., 2009).

The establishment of plantations is recognised as one component of achieving SFM (Chamshama et al., 2009). Planting of trees outside forests, along boundaries and in crop fields all contribute to SFM by providing timber and environmental services (Simmons, 2004). Tree planting activities in many African countries have been declining for decades and some countries have started to assess their programmes with a view to increasing species performance and productivity. There are increasing calls to apply SFM practices to increase the productivity of plantations and community woodlots. It is well established that productivity gains can be achieved for many plantation trees through the use of improved tree germplasm (Loo et al., 2014).

The use of good quality tree germplasm is a critical success factor in any tree planting programme. Tree breeding and use of good germplasm increases productivity, wood quality and lowers production costs, which, in turn, flow through as increased profits, sustainable production of goods and services and, ultimately, sustainable management of planted forests. Efficient supply of good germplasm is more pertinent now in many parts of Africa where availability of land for large-scale forestry plantation is limited, requiring the need for increasing productivity per unit area. If the plantation growing stock is to be improved, significant attention needs to be paid to its genetic constitution. This entails careful management through a clearly defined tree improvement strategy. There are increasing threats to forests and tree species from climate change, new diseases and pests. The challenge for sustainable forestry in Africa is to be as competitive as possible, and that means a continuous focus on increasing forest productivity through genetics, silviculture and forest health for both plantations and community forests. A timely supply of seed to tree planting programmes is critical and this can be achieved through a clear understanding of the tree planting needs of a country. Forecasting germplasm demands through an understanding of the rates of tree planting is an important step in improving seed supply (Denning, 2001).

5.2 TREE IMPROVEMENT STRATEGIES AND LINKAGE WITH SEED PRODUCTION

The first step towards sustainable productivity of plantations is to make sure that the most adaptable species seed source or hybrids is suited to the plantation environment and meet the targeted end use (Nambiar and Harwood, 2014). Species and provenance trials have been the scientific basis for successful tree planting for many decades (Koskela et al., 2014; Chamshama et al., 2009; Zobel et al., 1987), and for any tree planting programme there is need for continuous transfer and assessment of tree germplasm as well as accelerating research and development. The growing of trees is a technique that requires high quality scientific information to understand which species to grow where, where to source the planting material, how to manage the trees or stands to get optimal growth, range of products that can be harvested and what could be the environmental consequences of establishing the trees. The southern Africa region has experience in growing commercial tree species, agroforestry species, indigenous fruits and timber species.

5.2.1 COMMERCIAL SPECIES

Tree species and provenance trials provide the starting point for tree improvement and ultimately seed production. The basic elements of a tree improvement strategy and seed production has been described by Harwood et al.(2001) as follows:

i) conversion of natural stands to seed stands by selective thinning for production of run-of-the-mill seed;
ii) conversion of provenance trials to seed production by selective thinning to produce improved seed;
iii) establishment of progeny trials using selected plus-trees for the production of high quality seeds;
iv) establishment of clonal seed orchards from elite selection from existing trials;
v) controlled pollination between elite trees to create new families that will be established to produce full-sib seed, and,
vi) development of clones for the establishment of clonal forestry.

Southern Africa has led the rest of Africa in establishing trials of different exotic species. For example, a good number of provenance trials for several commercial species were set up in Zimbabwe (Tembani et al., 2014a).

Genetic improvement of exotic timber species for plantation development in southern Africa began in the 1890s through the importation of seed-lots of exotic species. Over the past century, many exotic species were tested and, today, pines, eucalypts and acacias are the most widely planted genera in the region. The most successful species include *Pinus patula, P. taeda, P. elliottii* and *P. kesiya.* Other potential *Pinus spp.* being tested are *P. tecunumanii, P. maximinoi, P. hererrai* and *P. greggii* (Nyoka, 1994). Breeding and selection of these species were initiated and today their selected populations are in advanced generations of selection and supplying genetically superior clonal orchard grade seed and clonal hybrids to tree planting programmes. For hardwood species, the most widely planted are *Eucalyptus grandis, E. cloeziana, E. camaldulensis* and *E. tereticornis.* Breeding and selection has also been practiced on eucalypts, and clonal hybrids are being deployed replacing traditional species to increased performance and productivity. *Acacia mearnsii* is the only widely planted acacia, grown for its bark used in leather tanning and for its wood which is converted into charcoal.

The real value of provenance trials is that they can provide seed that can be used to initiate a breeding programme if need arise. This is more crucial now in view of the germplasm constraint that can be imposed by the Nagoya Protocol and Material transfer agreements (MTA) between countries (an MTA is a contract that governs the transfer of materials between institutions for use in research). For example, the Australian Tree Seed Centre requires the right of access to information on the performance of seed supplied by them.

5.2.2 Agroforestry species

While improvement strategies for commercial species are clear, it is not so for multipurpose tree species. The end users are diverse and so are the end products and services. End users are usually rural farmers whose needs are continuously changing and who are risk-averse and may take long time to adopt new technologies. International NGOs, in partnership with national agricultural research institutions, took the lead in the evaluation of a number of species. The challenge of producing seed and deploying the germplasm still remains unresolved for many species. The classical breeding and seed deployment approach applicable to commercial species may not be applicable and new approaches need to be developed. For seed production, for example, Simmons (1992) suggested establishment of breeding seedling orchards that perform the combined functions of resource population, breeding population, progeny test and seed production area. Various deployment pathways have been suggested, e.g. via centralised government seed centres, NGOs, farmer-to-farmer exchanges and private seed merchants (Nyoka et al., 2011).

n recent decades, there has been a systematic introduction of species for integration into farming systems, for provision of food and fodder, for soil amelioration and for rehabilitating degraded lands. Information on provenances is becoming available through coordinated efforts between national research systems and international NGOs—such as the World Agroforestry Centre (ICRAF). However, there are still concerns on the availability of information on seed sources and the use of seed of unknown performance (Nyoka et al., 2011).

5.2.3 Indigenous fruit trees

A number of indigenous species have been identified as important sources of food for communities or raw materials for a wide variety of products. The list of priority species was identified by the World Agroforestry Centre in partnership with national institutions using participatory mechanisms. A large proportion of the fruits are still being collected from wild populations and sold at road sides and urban markets. Studies on the genetic variation of the species are done at two levels. First, the quality of fruits in terms of size, colour and taste is usually done on fruits collected from wild populations. Such information helps to inform the fruit collectors and processors on the best sources of good quality fruits. The second level is when seedlings are raised and planted at different sites to test for growth, performance and ultimately fruit characteristics. In Malawi, ICRAF is taking a lead on this work with the establishment of a number of provenance trials of some species such as *Uapaca kirkiana.* Vegetative propagation techniques where scions from mother trees with good fruit characteristics are grafted on rootstock, or propagated using air-layering or marcotting for species such as *U. kirkiana* and *Z. mauritiana* (Kalinganire and Koné, 2010).

Table 2 (below) lists the most common species and references on geographic variation studies. It is quite evident that a lot of research has been done in assembling genetic material which can form the basis for tree breeding programmes in the region.

Table 2. List of the most common indigenous fruit species and references on geographic variation studies.

Species	Country	References
Adansonia digitata	Malawi Namibia South Africa	Nyoka *et al*., 2014 ; Munthalia *et al*., 2012a ; Munthalia *et al.,* 2012b ; Sanchez, 2011 Nghitoolwa *et al.,* 2003 Shackleton, 2002; Leakey *et al.*. 2005
Parinari curatellifolia	Swaziland, Malawi, Mozambique, Zimbabwe	Akinnifesi *et al.,* 2006
Sclerocarya birrea	Malawi Namibia South Africa Zimbabwe	Nyoka *et al.,* 2014 ; Chirwa *et al.,*2007a Nghitoolwa *et al.,* 2003; Leakey *et al.,* 2005 Leakey *et al.,* 2005; Shackleton, 2002 Nyoka and Musokonyi, 2002
Strychnos cocculoides	Botswana Zambia	Oppelt *et al.,* 2005a; Oppelt *et al.,* 2005b Mkonda *et al.,* 2003
Uapaca kirkiana	Malawi Zimbabwe	Chirwa *et al.,* 2007b ; Mwase *et al.,* 2006 Nyoka and Musokonyi, 2002
Ziziphus mauritiana	Botswana, Malawi, South Africa, Zambia, Zimbabwe	Akinnifesi *et al.,* 2006

5.2.4. Threatened and commercially important indigenous species

The natural forests in southern Africa have high species diversity and some species have high valuable timber. For example, the flagship species for Zambezi teak forests that include *Baikiaea plurijuga, Pterocarpus angolensis, Guibourtia coleosperma* and *Afzelia quanzensis* are harvested for their timber. Other species harvested for their timber include *Dalbergia melanoxylon, Milicia excelsa* and *Khaya anthotheca (nyasica).* These species are mostly harvested by contractors given concession by Forest Departments. The pressure from harvesting some of these species in countries such as Mozambique needs to be counteracted by conservation of the target species (Mackenzie, 2006). In Zambia, many indigenous species are threatened from over-exploitation for charcoal production and locally managed charcoal production systems can be adopted to restore species and forests (Gumbo et al., 2013). The expectation is that after harvesting, forests are allowed to regenerate or are re-planted using seed collected from the forest before harvesting. Forest management plans usually require rehabilitation of harvested areas, but most Forest Departments are under-resourced to monitor the regeneration and restorative processes. The process of harvesting alters the population structure with the largest and well-formed trees usually targeted for harvesting. Remaining trees are usually impoverished in terms of genetic make-up. Understanding genetic impacts of forest management practices is crucial for conservation and management of forest genetic resources. Forest management practices based on selective and clear-cut systems followed by natural or artificial regeneration can impact population structure and mating patterns, thus gene flow and genetic diversity (Ratnam et al., 2014). This suggests that forest management plans need to take into account the genetic diversity and population structure of the species.

It is clear from the foregoing that while management plans are in place, they do not take account of the genetics and population structures of the species. A few species have received attention (Table 3). The net effect could be a progressive lowering of the genetic diversity and altering the population structures of the species leading to consequences in generations to come. Current emphasis is on conserving populations *in situ*, but whether these are comprehensive and adequately representative of the species distribution is unclear.

Table 3. List of the most common indigenous species and references on geographic variation studies

Species	**Country**	**References**
Pterocarpus angolensis	South Africa Zambia Zimbabwe Mozambique	Shackleton 2002 Mitwa *et al.,* 2010 Chisa-Kasumu *et al.,* 2009
Baikiaea plurijuga	Zambia Zimbabwe	Theilade *et al.,2001*
Melicia excelsa	Mozambique, Angola, Malawi	
Khaya anthotheca	Mozambique, Malawi, Zimbabwe	
Afzelia quanzensis	Malawi Mozambique	Mtambalika *et al*., 2014
Dalbergia melanoxylon	Mozambique, Zimbabwe, Malawi	

6. Country observations

The gains offered by tree improvement are key outcomes of forestry research and development in the five countries visited, and research is largely acknowledged as a means of delivering cost effectiveness, quality timber, other products and services. Apart from aligning tree breeding and seed production, an integrated deployment strategy that links genetic gain with operational tree planting practices is crucial to realising the improved yields, products and environmental services. Three fundamental components for a successful deployment strategy include: an understanding of site and growing conditions to which the material is best adapted, silvicultural practices that are well-matched to the material and short term measurements after planting to track the success or failure of the deployment exercise. The major challenge for the southern African countries is the high site diversity of the land suitable for plantation forestry, resulting in the need to utilise a number of species and modes of propagation. The end users and products are variable and the forest sector has to employ a number of strategies to achieve SFM goals. This study puts tree breeding at the core of afforestation policies and practices, hence the emphasis on afforestation and reforestation trends.

The following sections describe the situation in the countries visited highlighting the policies and trends in afforestation rates, main species planted, and capacity to produce and distribute germplasm. To put the description in context, the need for more investments in tree planting based on demand for products, projected deficits in products and current rates of tree planting are explored.

6.1. ZIMBABWE

6.1.1 Plantations in Zimbabwe

Various reports from the timber industry in Zimbabwe and the local media (Box 1) indicate that forest plantation resources in the country have declined significantly in recent years. The national timber resource base has fallen by 25 percent in the seven years to 2012, leading to company closures and almost 70 percent drop in export revenues. Zimbabwe has been facing a decline in afforestation and reforestation activities since 2000. The main factors behind the decline have been the land appropriation by new farmers and vandalism. Fire outbreaks and failure to rehabilitate the burnt areas also contributed to the decline in the land resource base. Insecure tenure by the private sector has also meant that most companies have reduced rates of extension planting. Low levels of capitalisation and lack of investment has meant that that most companies are focusing on short-term returns through harvesting and milling. Tree planting and management are no longer receiving priority. Cost cutting measures, such as contracting out harvesting are now normal as companies try to minimise operating costs. There is a proliferation of small-scale timber processing sawmills scattered throughout the forest estate making it difficult to plan and gather forest statistics.

The major forest plantation species in Zimbabwe are pines, eucalypts and *wattle*. Pine plantings are not restricted to *P. patula*, but also include *P. taeda, P. elliottii, P. kesiya*, *P. tecunumanii* and *P. maximinoi*. *P. elliottii* plantings have been restricted because of the resinous nature of the timber and because alternative species have shown superior growth rates, e.g. *P. tecunumanii* and *P. maximinoii* (Nyoka, 1994).

Box 1. Some media reports on the decline of the forest industry in Zimbabwe.

MUTARE — "Zimbabwe has depleted its timber plantation reserves, which were meant to cover 20 years, due to the reduction in plantation area, which fell from 108 214 hectares to a mere 80 000 hectares over the past decade. The collapse of the once vibrant industry has been attributed to various factors, from illegal settlements, mismanagement, to an ineffective timber replanting exercise." **Timber Industry In Doldrums** 6 Feb 2014
Kenneth Matimaire , newsdesk@fingaz.co.zw

"The exotic timber industry was arguably one of the mainstream industries, not only in Manicaland province, but the whole country. The eastern highlands were known for the lush pine, gum and other exotic timber plantations, but today the greenery has made way for a mosaic of burnt plantations and patches of maize in summer. The thriving timber industry is long gone***."***
Timber industry in limbo by Andrew Mambondiyani 08 November 2013 | 1939 Views Related Stories Zim Timber Industry will be dead soon |

The Zimbabwe National Chamber of Commerce is concerned about the collapse of the timber industry in Manicaland. ***06 May 2014*** **Timber industry collapse worries ZNCC**
"For a long time, timber was the biggest employer in Manicaland both in terms of direct employment and through downstream industries such as transport," said ZNCC president *09.10.13 by Farai Mabeza*

Source: TPF Annual General Report, 2014

Eucalyptus species planted for commercial or farm use are: *E. botryoides*, *E. camaldulensis, E. cloeziana, E. dunnii, E. urophylla, E. grandis, E, maculata, E. microcoryis, E. nitens, E. paniculata, E. pilularis, E. propinqua, E. punctata, E. regnans, E. resinifera, E. robusta, E saligna* and *E. tereticorni* (Mullin *et al.,* 1981). Only three species, *viz. E. grandis, E camaldulensis* and *E. tereticornis,* are planted on a commercial scale, but all the other species are still represented in old species and provenance trials at John Meikle Forest Research Station (JMFRS) and other research sites in the country (Table 4). They represent a comprehensive source of genetic material that can still be used in tree evaluation and breeding programmes.

Table 4. Details of species provenance trials established in Zimbabwe.

Species	Provenance trials		No. plus trees selected	Species	Provenance trials		No. plus trees selected
	No. of trials	Area (ha)			No. of trials	Area (ha)	
Pinus patula	14	23.25	463	*E. cloeziana*	1	1.57	8
P. echinata	2	1.37	-	Eucalypts (mixed)	18	51.34	14
P. elliottii	8	6.78	335	*E. microtheca*	2	4.58	-
P. taeda	12	11.65	263	*E. intexta*	1	0.49	-
P. tecunumanii	28	45.27	83	*Faidherbia albida*	10	26.37	
P. oocarpa	5	19.72	36	*Casuarina cunninghamiana*	5	2.05	-
P. kesiya	12	21.3	124	*A. holosericea*	4	1.49	-
P. caribaea	9	24.42	390	*A. erioloba*	1	0.61	-
P. chiapensis	4	1.94	72	*Azadirachta indica*	9	2.4	-
P. maximinoii	3	11.18	18	*A. auriculiformis*	2	2.91	-
Eucalyptus grandis	11	52.55	624	*A. mearnsii*	2	8.83	-
E. camaldulensis	9	24.71	143	*Acacia* species	7	7	-
E. tereticornis	7	19.78	146	*Araucaria cuninghamia*	1	1.84	-
E. citriodora	2	11.02	28	*Populas deltoides*	1	0.44	-
E. maculata	2	2.83	4	*Pinus merkusii*	2	0.67	-
E. dunnii	2	0.76	9				
E. saligna	2	4.72	30	**TOTAL**	**198**	**395**	

Source: Tembani *et al.,* 2014a.

Selections from these provenance trials have been improved for several generations and are now in seed and breeding seedling orchards for the main commercial species. General bulk collections are still made in some of the provenance trials to meet unexpected demands, e.g. the Sustainable Afforestation Association (SAA) is requesting seed of *E. cloeziana* to establish woodlots for the production of energy for tobacco curing. The increasing demand for new species not included in the mainstream breeding has renewed interest in some of the old introduction trials as sources of seed. Some of these trials have reached maturity and may still continue to provide valuable information for R&D. Selections from these provenance trials have been improved for several generations and are now in seed and breeding seedling orchards for the main commercial species. General bulk collections are still made in some of the provenance trials to meet unexpected demands, .

6.1.2. Trends in afforestation and reforestation

The Timber Producers Federation (TPF) compiles statistics on commercial plantings by various companies under its affiliation. Table 5 shows the decline in new plantings from 2000 to 2010. The implications of the lack of new afforestation areas is that tree growers have to increase productivity per unit area, which can partly be achieved through the use of improved germplasm (see South Africa case study in this report). As companies struggle to survive, replanting of *Eucalyptus* using seed has decreased and, as a cost-saving measure, old moribund stumps are still being managed for coppice production with ever decreasing yields, despite the fact that Zimbabwe has some of the best *Eucalyptus* germplasm in the region.

Table 5: Extent of new plantings from 2000 to 2010.

Year	New Afforestation (ha)				Total
	Pine	Eucalyptus	Wattle	Poplar	
2000	986	702	216	-	1904
2001	237	907	103	0	1247
2002	68	410	-	-	478
2003	15	132	78	-	225
2004	333	1184	-	-	1517
2005	75	627	-	-	702
2006	20	238	-	-	258
2007	427	214	-	-	641
2008	0	0	0	0	0
2009	0	0	0	0	0
2010	0	6	0	0	6

Source: TPF 2012

The rate of replanting has remained fairly flat between 2009 and 2013 (Table 6). From the discussions with forest industry experts, the reforestation statistics are not very accurate since the planning capacity in most companies has declined over the years as skilled manpower moved to other areas and sectors. There are reports of harvested areas being left to regenerate from wildlings which will be pruned and thinned as a future source of wood. The presence of new players in the sector, such as sawmilling contractors is making it difficult to gather forest statistics since most forest companies do not have capacity to monitor contractor operations. Most contractors do not have training in SFM (cut and run type operations). Thus, the accuracy of reforestation figures is questionable, especially from 2000 onwards when a number of factors propelled disinvestments in the forestry sector (inflation, land insecurity, political uncertainty and loss of skilled manpower).

Table 6. Rate of replanting felled areas (ha) in Zimbabwe

Year	2009	2010	2011	2012	2013
Replanting (ha)	5 954	4 071	8 660	4 010	3 844

Source: TPF 2014

At a macro-level, there appears to be no conscious support to the forestry sector in Zimbabwe – e.g., the Zimbabwe Agenda for Sustained Socio-Economic Transformation (ZIMASSET, 2013) does not make any reference to the need to invest more in tree planting and management. This is despite a projection of GDP growth of 7.0 % that would result in increased demand for timber and other products in the country.

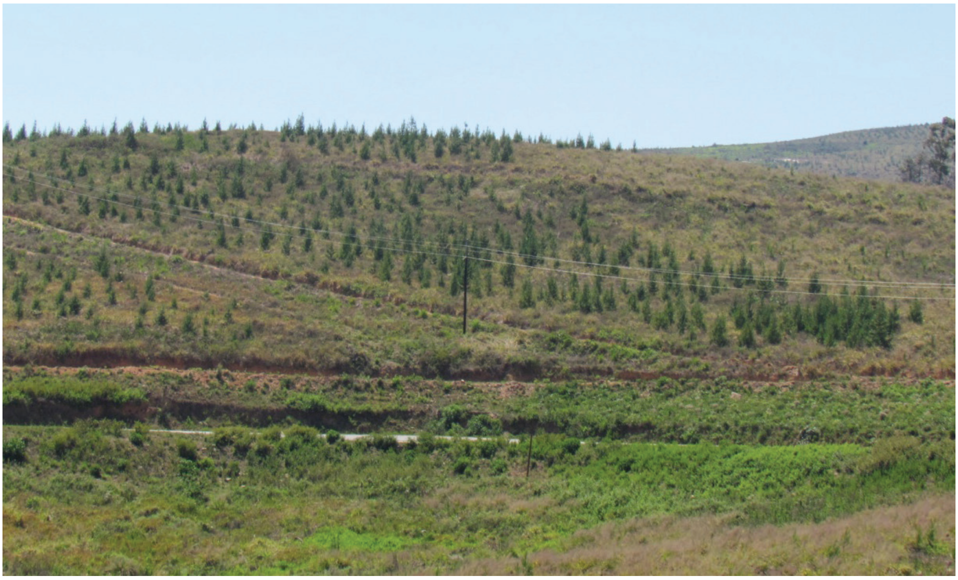


Photo 1. An industry in crisis – poor silvicultural management resulting in uneven survival and poor site capture of young pine trees (photo by C. Marunda, 2014).

6.1.3. Woodlots and community tree planting

Tree planting by farmers, communities and the general public is supported by the Forestry Commission of Zimbabwe. The organization promotes tree planting by encouraging the establishment of community woodlots based on fast growing eucalyptus species mainly for the provision of fuelwood, fencing posts and poles. Other species promoted include Acacias, mainly *Faidherbia albida* and indigenous species. Planting is encouraged through the promotion of agroforestry practices using MPTS or other local indigenous species, and through the National Tree Planting Day held every year during the first week of December.

Data on the nationwide statistics on tree planting is fragmented as a result of institutional arrangements were some private and non-governmental entities conduct separate tree planting programmes (and compile their own statistical data). The Forestry Commission may not be directly involved but the seed centre is the first contact point for seed for many tree growers. This creates a challenge in the compilation of a national statistical average for tree planting programmes as aggregating the individual data sets from various organizations is often a challenge. However, the Forestry Commission conducts regular data compilation on general purpose tree planting, through its extension department, based on the information from various districts and provinces within in the country. Table 7 shows statistics of tree planting from 2006-2013. It is clear that, in most cases, targets set are not met perhaps due to lack of adequate tree germplasm and technical and financial support. It is also difficult to get the list of species planted. This information will be useful for the seed centre when planning for seed collection missions.

Table 7: Tree planting statistics from 2006 to 2013

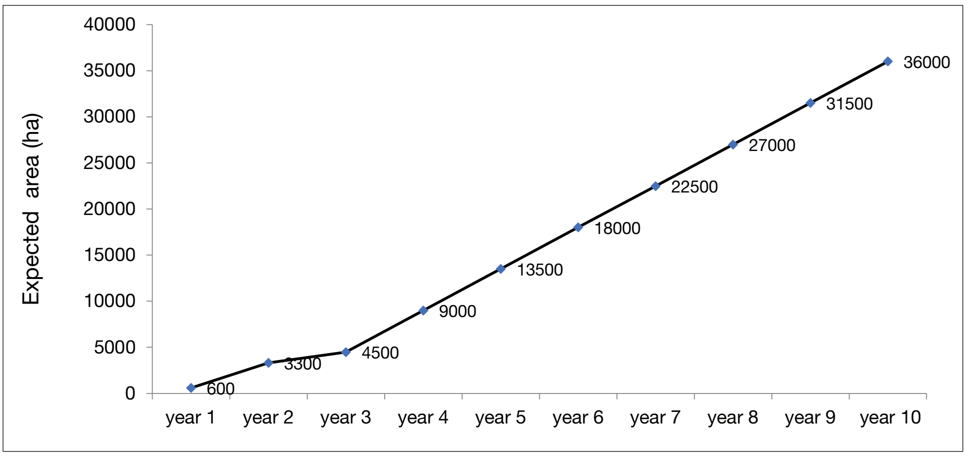
Year	Seedlings raised (1000)	Target (1000)	Trees planted (1000)	Target (1000)
2006	5 330	5 095	8 054	4 595
2007	12 862	3 760	2 073	3 081
2008	3 407	10 119	2 626	4 818
2009	4 597	2 084	1 945	1 853
2010	1 543	2 222	2 852	1 854
2011	2 978	5 430	2 057	5 000
2012	4 018	7 093	4 167	6 741
2013	8 722	10 333	4 733	10 000

Source: Forestry Commission, Conservation and Extension annual reports: 2006-2013.

Indications from discussions with extension staff are that tree mortality is very high, with survival averaging 60%. The causes include poor site species matching, moisture stress, termite attacks, lack of care (such as weed control), fires, browsing and trampling by livestock. Apart from eucalypts and a few agroforestry species introduced and tested for performance and adaptability by FRC and other institutions such as ICRAF, there has not been any systematic evaluation of species for these general plantings, hence the high rates of failure. This is despite a long list of priority species that have been identified (e.g. Rukuni *et al*., 1999) and many other species identified as having potential, e.g. *Bivinia jalbertii* (Tembani *et al*., 2014b).

The entry of many small-scale farmers into tobacco growing has created a huge demand for fuelwood for curing. For example, the number of tobacco growers registered increased from 22 000 in 2012 to 106 451 in the 2014 growing season (Kamuti, 2013). High rates of deforestation have been reported in the media and, to reverse the trends, the tobacco industry formed the Sustainable Afforestation Association (SAA) with a mandate to grow trees in woodlots to provide firewood for tobacco curing and reduce deforestation of natural woodlands. About 600 ha have so far been planted and there are projections that about 36 000 ha will be planted by 2020 (Figure 2) (SAA presentation at TPF AGM, 2014). This has resulted in a significant increase in the demand for tree seeds, particularly of eucalypts. The Tree Seed Centre has often failed to provide enough seed of the required species and has led to SAA to make seed enquiries abroad (e.g. for eucalypts in Australia). Demand for seed for species such as *E. cloeziana,* which produces denser wood than traditional species (*E. camaldulensis* and *E. tereticornis*), is being preferred. The limitation with *E. cloeziana* is its specific site requirements (fertile soils and good rainfall) found only in the Eastern Highlands of the country. The increased demand for seeds by SAA has renewed interest in exploring the potential of new species such as lesser-known Eucalypts. There has been mention of using *Faidherbia albida* and other acacias since they are fast growing, and also been suggestions of planting the giant bamboo (Rukuni, Tobacco Research Board, personal communication), or using wattle, which is considered a weed in the Eastern highlands of the country.

Figure 2. Expected afforestation area for the establishment of woodlots for providing energy for tobacco curing by SAA (year 1= 2010) (Source: SAA presentation at TPF AGM, Mutare, Zimbabwe, 2014).



6.1.4. Threats to eucalypt germplasm

Eucalyptus species are widely planted in Zimbabwe for the production of poles and sawlogs, as well as in communal woodlots and as individual trees for poles and firewood. Routine surveys of plantations and woodlots by the Research and Development division have shown that three major pests are attacking the commonly grown species, *viz. Leptocybe invasa* (Blue Gum Chalcid), *Thaumastocoris peregrinus* (Bronze bug) and *Glycapsis brimblecombei* (Red Gum Lerp Pysllid), which have been reported in Zimbabwe (Mushongahande, 2012 and 2014). These pests have also been reported in South Africa (Nadel *et al*., 2009; FAO, 2012), Mozambique (Chirinzane *et al.,* 2014) and Malawi (Chilima et al., 2008).

These three pests are thought to have been introduced through importation of eucalypt clonal hybrids from South Africa through movement of logs with bark. For example, in Zimbabwe, 500 ha that were planted with *Grandis* x *Camaldulensis* hybrids imported from South Africa were wiped out by the blue gum lerp (Mushongahande, personal communication, 2014). The pests are so wide spread that most plantations and woodlots in the country are affected. Control is being tried using biological means through parasitic wasps and instituting phytosanitory measures such as restricting movement of seedlings (Mushongahande, personal communication, 2014).

Figure 3 a) Galls on Eucalypt tree (Blue gum chalcid); b) Red gum lerp attack showing the lerps (photos by M. Mushongahande, 2014).

The implication of these attacks is that a tree germplasm resource that is widely planted for many uses has become threatened. Controlling the pests through chemical and biological control is difficult and one of the solutions that has been suggested by the Research and Development Division has been to introduce new species of *Eucalyptus* such as *E. dunnii*, or breeding for resistance in existing species or planting other species. Discussions with staff at the Forest Research Centre indicated that there could be a need to switch to other species, such as Acacias, to be able to meet the gap that could emerge if the eucalypt resource is decimated by the pests. The expected implication of these challenges is the discarding of eucalypts as a preferred species for planting programmes and this could result in increased pressure on indigenous tree resources. This would mean that Zimbabwe will have to invest more into R&D and possibly initiate species and provenance trials to replace the gap that will be left by the widely planted eucalypts (alternative species include *F. albida, E dunnii, A. polyacantha, P. thonningii*).

6.1.5 Tree germplasm production in Zimbabwe

Pine and eucalypt species

Zimbabwe has a longer history of seed production and distribution than most countries in the Southern African region. Zimbabwe distributes seeds of pines, eucalypts, acacias and many other indigenous species to local, regional and international clients. The Forest Research Centre has a long history of tree breeding and seed production of pine and eucalypt species. As of 2000, the country had about 165 seed orchards situated in various locations within the country (Table 8). All seed sources are based on selections of plus trees that are grown in seedling seed orchards, or seed is collected from provenance trials that have been thinned leaving the best trees.

There is need to have empirical figures on the state of seed sources, especially seed orchards, after uncontrolled fires and clear-felling happening in plantation on all estates (TPF, 2014). Seed orchards are some of the best maintained tree plantings and often they do attract attention from vandalism resulting in people illegally cutting down the trees for firewood and poles.

Clonal hybrids of eucalypts have also been introduced in Zimbabwe. Seeds of the hybrids between *E. grandis* with *E. camaldulensis, E. saligna, E. tereticonis* and *E. urophylla* were obtained in 1990 from Hans Merensky Holdings in South Africa. Hybrid parents of *E. saligna* were intensively selected clones in seed orchards, while those of *E. camaldulensis*, *E. tereticornis* and *E. urophylla* were selections in provenance trials. In all the hybrids, *E. grandis* trees were used as the female parent (Gwaze *et al*., 2000; Madhibha *et al*., 2013). Some of the hybrids have performed better in terms of growth rates and tree form than pure species especially in the drier parts of the country. The hybrid material in Zimbabwe presents a good resource that can be used as propagation material for establishing plantations and woodlots especially in the marginal areas. However, there is concern about the rooting ability of some of the clonal material and it has also proved to be expensive and labour intensive to establish clonal hedges and raise the propagules (Griffin, 2014).

Zimbabwe received considerable support from the International Development Research Centre of Canada (IDRC) for first establishing the Regional Tree Seed Centre (1988 to 1992) and later on by CIDA to participate and contribute to the SADC Tree Seed Centre Network (1992 to 2000). Over the last decade, the amount of seed and revenue from seed distribution and sales has declined. The reasons for this decline are many, including lack of investments in R&D, old seed orchards which are no longer productive, vandalism (cutting down orchards and fires), and a general decline of demand from some countries such as South Africa that have established their own seed orchards or are now planting more clonal hybrids than seed (Tembani *et al.,* 2014a).

Table 8. Number of seed orchards (SOs), breeding seed orchards (BSOs) and their respective areas and level of genetic improvement (as at 2000).

Species	Number of SOs	Area (ha)	No. of BSOs	Area (ha)	Generation
Eucalyptus grandis	6	15	11	25.5	2nd , 4th
E. camaldulensis	17	33	29	46.4	1st, 2nd, 3rd,4th
E. tereticornis	9	10	8	8.3	2nd, 3rd
E. citriodora	1	0.6	3	2.6	1st
Pinus patula	26	46	5	17	1st ,2nd
P. taeda	24	33	8	6.6	1st, 2nd
P. elliottii	28	61	8	10.2	1st ,2nd
P. kesiya	17	53	3	5.5	1st ,2nd
P. oocarpa	7	22	2	1.7	1st
P. pseudostrobus	1	0.7	1	0.4	1st
P. maximinoii	4	19	-	-	1st
P. tecunumanii	14	18	-	-	1st
P. caribaea var. *hondurensis*	1	0.6	-	-	1st
P. caribaea var. *bahamensis*	1	0.6	-	-	1st
P. caribaea var. *caribaea*	1	0.6	1	2.0	1st
P. palustris	1	0.5	-	-	1st
P. chiapensis	4	6	4	4.9	1st
Cupressus lusitanica	1	0.6	1	0.6	1st
Total	**165**	**322**	**84**	**132**	

Source: Tembani *et al*., 2014a.

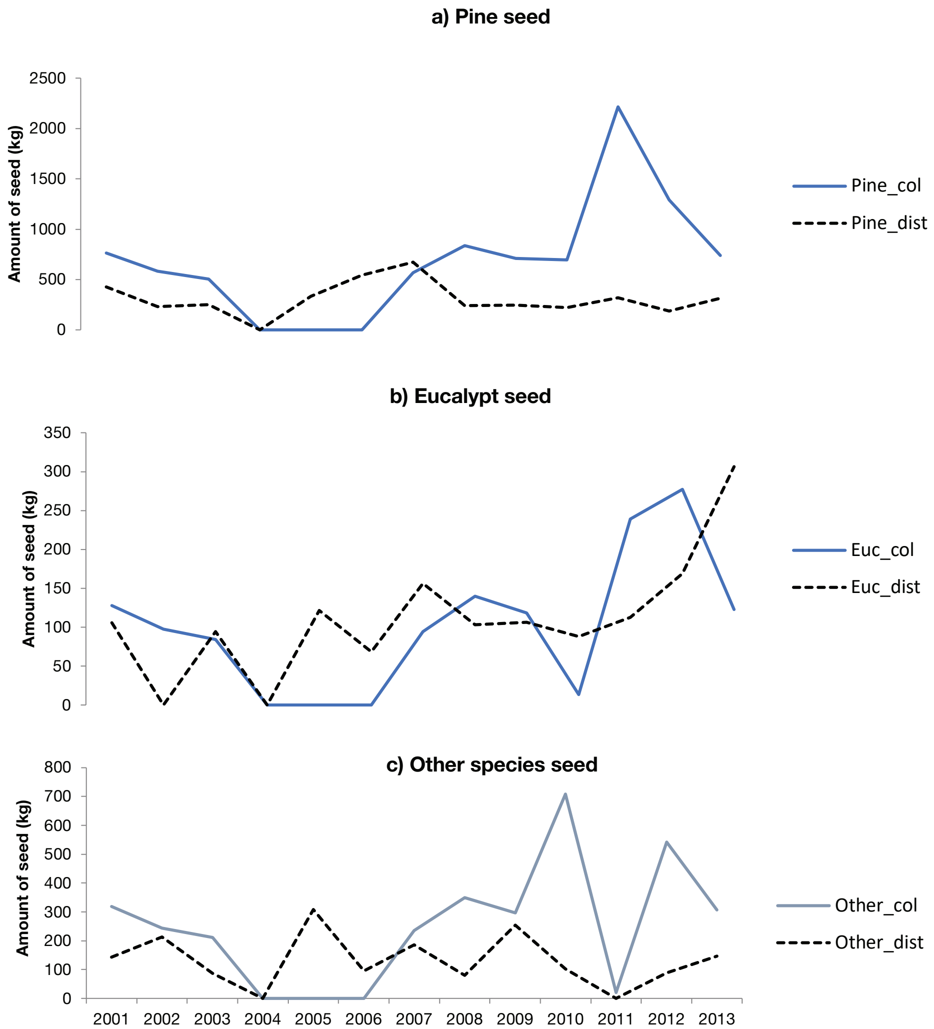


Figure 4. Amounts of eucalypts, pine and other tree species seeds collected and distributed in Zimbabwe from 2001 to 2013 (adapted from Tembani, undated).

Old seed orchards, constant break down of cold room facilities and power cuts have often been blamed for poor viability of seed. Clients have complained of poor germination of seed (*P. patula* in Mozambique and *Eucalyptus* species in Zimbabwe), mixed seed-lots (e.g. *P. patula* mixed with *P. taeda* seed in South Africa). This has meant that Zimbabwe has become an unreliable supplier of good quality seed with clients sourcing seed from elsewhere (in the Americas and Australia) (see case studies for Malawi and Mozambique in this report). However, it is equally important to point out that Zimbabwe still has a unique collection of provenance trials, resource stands and seed orchards of many commercially important species and can provide a good source for a broad-based tree improvement programme in the region (Gumbie, personal communication, 2014).

The Tree Seed Centre's seed distribution trends over the 13 years for pines, eucalypts and other species are indicated in Figures 4 (a,b,c; above). There has been a general decline in the sale of pine seed over the period due to reduced demand. Seed collection shows an opposite trend probably due to speculative collection targets in anticipation of increase in demand. There is an indication of a steady increase in the sale of *Eucalyptus* seed probably due to high demand for wood for tobacco curing. The drawback of having more seed in stock that is the cold conditions required to retain seed viability are not being met, due to frequent power cuts in the country. Hence, large amounts of seed lose viability. There are reports of low viability of some seed originating from the centre (Marufu, Kwesha, personal communication, 2014).

It is evident that Zimbabwe had capacity to produce seed for a range of species. Since 2000, investment in forest research has declined significantly resulting in the Forest Research/Seed Centre failing to maintain seed orchards and unable to meet seed demand for all species (Tembani *et al*., 2014a). A number of seed and breeding seedlings orchards have been lost to vandalism and fire outbreaks. 40-year old seed orchards of *P. taeda, P. elliotii* and *P. kesiya* are no longer as productive and FRC is rejuvenating the seed orchards by re-grafting scions on to new root stocks. New pests that are attacking *Eucalyptus grandis*, *E. camaldulensis* and *E tereticornis* have created an urgent need to test new species that have the same fast growth and produce the same products. This is occurring against a background of increased demand for eucalyptus seed for establishing woodlots to supply wood energy for tobacco curing.

Seed orchards were also established for *P. maximinoi* and *P. tecunumanii* in 2011, but these are producing low quantities of seed. There is some evidence that these species are generally shy seed producers (Nyoka and Tongoona, 1998; Gapare *et al*., 2001). Low seed set is a cause for concern since the two species out-perform the traditional *P. patula*. More research needs to be done to identify the best sites to maximise seed production (Nyoka and Tongoona, 1998).

Indigenous tree species

Collection of indigenous species is opportunistic and there are no observable trends (Figure 4). Collections are based on availability of funding and seed production cycles and are done during mast years (when trees have high seed yields), which reduce costs per kg of seed collected as huge amounts of seeds are collected. In terms of amounts collected, *F. albida* is the main target species because of increasing demand for its fast growth and provision of fodder (both leaves and pods). Other species are collected to supply demand for aesthetic plantings or specific seed requests for research or project plantings.

Agroforestry tree species

The collection of agroforestry tree species is also on an *ad-hoc* basis as the demand is not very strong or is simply not well known. Demand is usually driven by funded projects where these species are promoted. ICRAF has introduced a number of species and has established demonstration and provenance trials in Zimbabwe. Some of these trials have been maintained as sources of seed, and the amount of seed collected by the seed centre is not large (Table 9). Estimation of the demand for such species is very difficult since farmers either collect their own seed or exchange seed amongst themselves.

Table 9. Trends in Agroforestry tree species seed production between 2000 and 2010.

Species	Seed production (kg) in Zimbabwe		
	From	To	Mean
Gliricidia sepium	-	-	-
Calliandra calothyrsus	-	-	-
Acacia angustissima	0.5	1	0.85
Leucaena pallida	-	-	-
L. leucocephala	3	9	7
L. diversifolia	0.5	2.5	1.7
Tephrosia spp.	-	-	-
Senna siamea	-	-	-
Senna spectabilis	-	-	-
Moringa oleifera	4	15	8
Faidherbia albida	11	39	17
Acacia polyacantha	6	23	9
Acacia spp.	5	37	22
Albizia lebbeck	-	-	-
Albizia spp	1	9	6

6.1.6. Key findings in Zimbabwe

- The plantation forest industry in Zimbabwe is in decline as evidenced by declining rates of afforestation and reforestation.
- FRC has a broad range of species represented in provenance trials, resource stands and seed orchards which form a solid base for tree breeding and improvement, not only in Zimbabwe but in the region. While some of the orchards are no longer productive, there are efforts to rejuvenate some of them through re-grafting and replanting.

- Zimbabwe has established clonal orchards of *P. tecunumanii* and *P. maximinoi* which perform better than the traditional *P. patula*. There are, however, concerns that the species are shy seed producers and there could be a short to mid-term shortage of seed for plantation establishment.
- While efforts are being made to raise eucalypts for the supply of energy to the small-scale tobacco industry, there are still problems with accessing good viable seed and the species choice is narrow.
- The emergence of deadly pests that are attacking the commonly planted eucalypts is a source of major concern. The value of eucalypts in supplying timber, fuelwood, poles and posts is well documented and if there is a gap in supply of products, then many livelihoods, especially of the rural communities, will be affected. Deforestation rates may increase as people will resort to natural forests.
- Frequent breakdown of cold room facilities due to power cuts, vandalism of seed orchards, fires and lack of funds are preventing the seed centre from operating at full capacity. If this continues, the seed centre risks losing its regional market to overseas suppliers (for example, forest companies in Mozambique are procuring seed from faraway countries in the Americas).
- Given the backlog in afforestation and reforestation, Zimbabwe needs to invest more to maintain its tree breeding and seed production operations if it is to meet current and future demand for tree germplasm. This presents a strong argument for more investment in R&D.

6.2. ZAMBIA

6.2.1. Plantations and main species in Zambia

In 1963, the Government of Zambia started to invest significantly in establishing forest plantations to augment timber supplies from natural forests. The Forest Department was responsible for the establishment of forest plantations with exotic species of *Pinus*, *Eucalyptus* and *Gmelina* supported by a loan from the World Bank. There are about 57 000 ha of plantations in the country of which 54 010 ha are managed by the Zambia Forestry and Forest Industry Corporation (ZAFFICO) (Table 10). The rest of the plantations are managed by private landholders and communities. About 85 percent of forest plantations are in the Copperbelt. Since plantation establishment in the country, substantial amounts of timber have matured and a significant amount of sawn timber comes from these plantations. There was not much investment in tree management in the plantations resulting in some of the trees being of poor form and some forests areas were ravaged by repeated fires (Sichilongo, personal communication, 2014).

Table 10. Plantation statistics in Zambia.

Location	Pines (ha)	Eucalypts (ha)	Others (ha)	Total (ha)
Ndola	16 710	254		18 487
Chati	5 472	6 847	116	12 548
Ichimbe	10 973	889	74	11 936
Lamba	4 061	185	0	5 866
Forest Department	2 921	2 207	45	5 173
Total	**40 137**	**10 382**	**235**	**54 010**

Forest management in general started to decline in the late 1970s for a number of reasons. For example, the general decline in the national economy resulted in reduced budgetary allocations to the forest sector. However, during the past decade, the economy of Zambia has improved and there is an increase in demand for timber and attention is being paid to good forest management.

Pines, eucalypts and other exotic species

The main plantation species are *Pinus kesiya, P. oocarpa, Eucalyptus grandis* and *E. cleoziana*. Others are *Gmelina arborea*, *P. merkusii*, *P. michoacanus*, *E. tereticornis*, *E. camaldulensis* and a hybrid between *E. tereticornis* and *E. camaldulensis* (Sekeli and Phiri, 2002). Experimental research records show that 80 *Eucalyptus* species and 35 *Pinus* species have been tested in Zambia in species trials and those indicated above have been the most successful. The total area occupied by *Pinus* spp. is considerably higher than that of *Eucalyptus* spp. The choice of *E. cloeziana, E. grandis, P. oocarpa* and *P. kesiya* as the major species for planting was based on superior growth in high rainfall areas and their ability to compete with, and suppress, noxious weeds. *P. kesiya* is the most important commercial plantation species (Armitage and Burley, 1980). In 1999, there were approximately 26 000 ha of *P. kesiya,* i.e. nearly half of the total area under commercial plantations in Zambia (Sekeli and Phiri, 1999).

In terms of the planted net area of *P. kesiya,* the most important country in the world is Madagascar, followed by Zambia. Commercial scale planting of *P. kesiya* started in 1961. Provenances from Vietnam, the Philippines and Madagascar were selected on the basis of results from some trial plots. The genetic material of *P. kesiya* also included two local land races of Philippine and Vietnamese origin (see Hansen *et al*., 2003). Tree improvement work has remarkably improved the stem form. *P. oocarpa* is the second most popular species in Zambia with the Angeles provenance out-performing *P. kesiya*, and has since replaced *P. kesiya* as the first pine species in planting programmes (Mikkola, 1989).

6.2.2. Diseases threatening tree germplasm in Zambia

The plantation forests in Zambia are located mainly in the Copperbelt region in the northern part of the country, an area of high rainfall and high temperatures. These climatic conditions are ideal for diseases such as fungal pathogens. Surveys by Chungu *et al*. (2010) identified several previously unknown diseases of *Eucalyptus* spp. in the country, including fungal pathogens that reduce timber quality and cause tree mortality. The survey recommended increased and improved training of foresters regarding tree health issues, more effective quarantine, silvicultural practices and, most importantly, the establishment of sound breeding and selection programmes.

6.2.3. Afforestation in Zambia

The long term sustainability of forest plantations in Zambia is threatened by low annual replanting rates, and the lack of policy and strategic plans on expansion of forest resources. Figure 5 shows afforestation rates increasing in the early 1980s followed by a sharp decline after 1986. Currently, the rate of afforestation ranges from 100 to 350 ha/y. An analysis by Nshingo (2006) showed that the annual consumption of pine wood in Zambia rapidly increased from 2000 to 2006 with an average rise of c. 15 % per year. This rapid increase in wood consumption led to serious concerns on the long-term sustainability of wood supply in the country. There are reports that Zambia has started importing sawn timber from Malawi and treated transmission poles from Zimbabwe (Makumba, Director of Forestry, personal communication, 2014). The low rates of planting and predicted deficits in wood supplies would require increased rates of planting in the future.

ZAFFICO has embarked on an initiative to restock plantations where trees have been cut for timber production. This initiative will run for five years and the target is to plant 350 ha/y (Nshingo, news article 2014). The Government of Zambia has also availed a Forest Industry Credit Facility to the value of USD 500 000 per year targeting the rural people in Zambia to participate in plantation development. Part of these funds will be used to establish c. 10 000 ha of planted trees per province (10 provinces in total) through the National Tree Planting Programme. The programme, during 2013/2014, aimed at raising close to 25 million tree seedlings country-wide to be planted during the tree planting season. The goal of the programme is to ensure future sustained supplies of wood for use for construction, power transmission poles, carpentry and joinery and wood based panels, and in the long term contribute to the reduction of the high rate of deforestation and forest degradation that Zambia is currently experiencing.

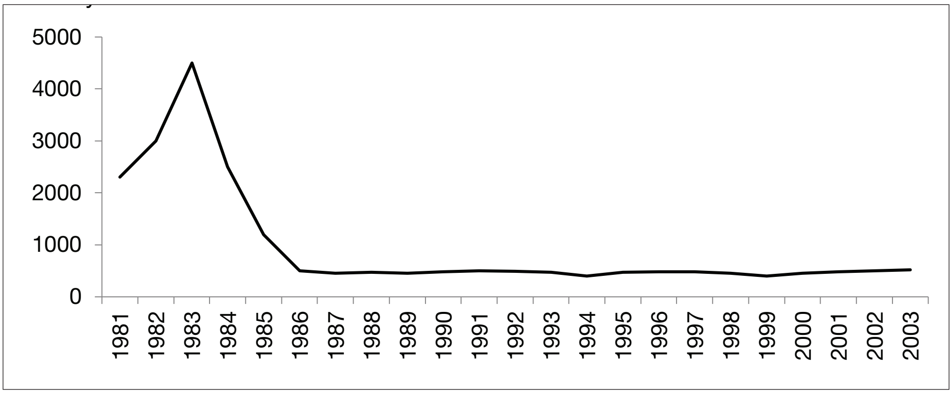


Figure 5. Rate of afforestation at one of the estates owned by ZAFFICO from 1981 to 2003 (adapted from Nshingo, 2006).

The Sixth National Development Plan (2011-2015) sought to strengthen the capacity of the Forestry Department to reverse deforestation through establishing new and expanding existing plantations, promoting village/school nurseries and woodlots, and by rehabilitating infrastructure, e.g. the Zambia College of Forestry and Tree Seed Centre. The target was to plant 1500 ha in 2011 rising to 2 000 ha by 2015. These strategies would demand investment in species selection, improvement and supply of good quality germplasm. The Chief Forestry Research Officer raised the concern that while this is a good idea it has not been matched with appropriate investment in species selection and some of the target areas are not suitable for establishing plantations or woodlots. This demonstrates the usual assumption by most tree planting programmes that trees can grow anywhere ignoring the most important aspects of site-species matching. There are a number of failed plantations due to poor choice of species and poor management after planting, browsing and fires. In a study on the survival of *E. grandis* and *G. arborea*, which are common species for rural afforestation programmes, Chidumayo (1988) found poor survival attributable to poor care after planting, moisture stress and termites. An important question that arises when considering farm forestry and/or rural tree planting is the suitability of the species to the local environment and the desired end product from the plantation. This question is applicable to many planting activities in the southern African region.

6.2.4. Tree germplasm production in Zambia

Commercial species

Zambia, like all the SADC countries, received support and participated in the SADC TSCN project between 1992 and 2000. During the visit, it was quite clear that the NTSC in Zambia requires new support as the equipment and facilities have deteriorated to a point of no use. The seed centre is only able to process about 100 kg/y of seed and does not meet the requirements of the National Tree Planting Programme and the private sector (ZAFFICO).

Discussions with the Chief Research Officer revealed that, at one point, Zambia had to purchase *P. kesiya* seed from Vietnam to support tree planting programmes. A seed orchard of *P. oocarpa* was established a few years ago and is being assessed for flowering. The orchard can become an important seed source for most tree planting activities in the region that use this species (e.g. in Mozambique). Most eucalypt seed is collected from plantations that have been thinned and plus trees selected. The Forestry Department manages about 60 ha comprising seed orchards and thinned stands with select seed trees. One private company imported eucalypt hybrids from South Africa but, unfortunately, the plantation is not doing well due to tip-dieback of the planted trees. This problem of eucalypt clones imported from South Africa has also been reported in Zimbabwe and highlights some of the problems with hybrids. They are usually bred for specific sites and tend to have a narrow genetic base, and when moved out to new environments, they tend not to perform to expectations.

Agroforestry tree species

A number of agroforestry tree species have been evaluated in Zambia through ICRAF projects based in Chipata in the north eastern part of the country (Table 11). Seeds of most of them are supplied through donor funded projects, farmer-to-farmer exchanges and hence it is difficult to monitor genetic quality and amount of seed exchanged (Nyoka *et al.,* 2011). Discussions with the Chief Research Officer, Forestry Department, on the improvement and domestication of MPTS and other indigenous species raised interesting points. The demand for these species is largely driven by donor funded projects (e.g., for use in conservation farming systems) and when the projects end, the priorities of farmers also change, meaning that any efforts to improve the species also ends. This presents challenges to the department and the seed centre to put in place a programme for improvement and collection of these species. There are a lot of donor funded community tree planting projects in Zambia and it is difficult for the forestry department to keep track of the seed requirements, planting statistics and survival of the planted trees.

Table 11. Agroforestry tree species introduced in farming systems in Zambia.

Species	Use
Tephrosia vogelii Hook f.	Soil fertility and pesticide
Gliricidia sepium (Jaq.) Walp	Soil fertility
Sesbania sesban (L.) Merrill	Soil fertility
Cajanus cajan (L.) Millsp	Food and soil fertility
Tephrosia candida DC	Soil fertility
Strychnos cocculoides Bak	Fruit and medicines
Senna siamea (Lam.)	Fuel wood and medicine
Uapaca kirkiana Mu̇ll. Arg	Fruits
Ziziphus mauritiana Lam.	Fruits
Jatropha curcas L	Oil production
Acacia crassicarpa A. Cunn	Fuel wood
Sclerocarya birrea (Rich.) Hochst	Fruits
Azadirachta indica A. Juss	Medicinal value

Source: adapted from Sileshi *et al.,* 2008.

Indigenous tree species

Zambia also has an active collection of indigenous species. The most important ones include *Julbernadia paniculata, Brachystegia spiciformis, B. boehmii, Colophospermum mopane, Isoberlinia angolensis, Diplorhynchus condylocarpon, Pseudolachnostylis maprouneifolia, Pterocarpus angolensis, Erythrophleum africanum* and *Parinari curatellifolia* (FRA, 2010). *Baikiaea plurijuga* has been selected as a target species for conservation (Danida Forest Seed Centre, 2001) and recently the Seed Centre collected up to 5 tons of seed from the species for establishing conservation and resource stands with the aim of conserving the genetic diversity. Some collection of indigenous fruits and seeds are carried out to supply material for testing, e.g. collection of *S. cocculoides* were done to evaluate the characteristics of fruit collected from different sources (Mkonda et al., 2003).

Figure 6. Fruits of *Strychnos cocculoides* being sold on the road side. Sometimes seed collectors would buy fruits from road-side sellers and extract the seeds (photo by M. Mutamba, undated).

6.2.5. Key findings in Zambia

- Zambia has the potential to increase its rate of afforestation since it has the land and supportive policies (e.g., 6th NDP and the Forest Industry Credit Facility).
- The projected deficits in timber especially sawlogs would require an increase in tree planting if future demand is to be met. If the high rates of deforestation are to be curtailed there is need to invest more in tree planting by the private sector and support the efforts by communities and farmers.
- The Seed Centre in Zambia needs support to increase its capacity to produce pine and eucalyptus seed rather than depending on imports from as far afield as Vietnam.
- The supply of agroforestry species appears not to be a major concern for the Forestry Department as most of the seed is supplied by NGOs and ICRAF. There is evidence of farmer-to-farmer exchanges. The major concern, however, is genetic quality control as there is no monitoring of seed movement.
- Setting priorities for species for rural afforestation is difficult since priorities for

species and end users change all the time depending on the objectives usually set by NGOs and funding agencies.

- Survival rates of planted trees under rural afforestation programmes are very low.

6.3. MALAWI

6.3.1. Plantations in Malawi

Malawi has c. 120 000 ha of plantations of which the government owns 75 000 ha. About 68 000 ha are planted under pine species and the rest with cypress, cedar and *Eucalyptus* (blue gum). The largest single plantation is the Viphya Scheme which was initially planted for pulpwood. However, the pulpwood plant was not constructed and the timber is being harvested for sawlogs and poles. To tackle the deforestation problem facing Malawi, the Forest Department, under the Wood Energy Project funded by the World Bank, embarked on the establishment of fuelwood and pole plantations country wide. A total of 22 895 ha were established, bringing the total of plantations under the Forestry Department to 97 210 ha. The private sector has also established c. 36 000 ha of fuelwood and pole plantations mostly on tobacco and tea estates (USAID/Malawi, 2005). Other notable plantations include those in Chongoni in Dedza, Zomba and Mlanje.

Initial work on tree breeding started in the early 1900s focusing on indigenous trees such as *Widdringtonia nodiflora* (syn. *W. whyteii), Pterocarpus angolensis* and *Khaya nyasica*. Later on, introduction of pines (*Pinus patula, P. elliottii, P. taeda*), *Eucalyptus* spp and cypress were done in the form of unreplicated arboretum plots (Nkonja, 1982). The plantation resource is mainly made up of *P. patula, P. kesiya, E. grandis* and *E. camaldulensis* and has for many years remained un-pruned and un-thinned, resulting in trees of poor stock.

6.3.2. Afforestation and forestation activities

The plantation resource is now being harvested for sawn-timber targeted for both domestic and regional markets (exports to Zambia and Kenya). Harvesting and processing logs is through an exclusive concessionary arrangement. Most concessions have been given out to foreigners who front up locals. Due to lack of appropriate monitoring mechanisms by the Forest Department, there is evidence of under-reporting of volumes harvested and extracted and most concessionaires have no capacity to replant (Mtika, 2013). This poor arrangement is resulting in low rates of replanting of harvested areas – only 1 600 ha were replanted in 2012 and this is gradually leading to a replanting backlog.

Table 12. Target and actual numbers of trees planted in Malawi under the National Forestry Season, 2013 to 2014.

Region	Target (# of trees) (1 000)	Production (1 000)	Trees planted (1000)
North	10 000	8 961	7 390
Center	35 000	32 979	40 785
South	15 000	15 022	15 022
Total	**60 000**	**56 962**	**63 197**

Malawi Forestry Extension Internal Report (Nkolokosa personal communication).

General tree planting in Malawi is supported by the government through the National Forestry Season programme that encourages all Malawians to plant trees between December and April every year. The target is around 60 million trees and Table 12 above shows the target for the years 2013 and 2014. Commonly planted species are *Khaya anthotheca*, *Senna siamea, S. spectabilis*, *Eucalyptus* spp., *Albizia lebbeck, Faidherbia albida, Azadirachta indica, Syzygium cordatum, Moringa oleifera*, *Pinus* spp.*, Afzelia quanzencis* and bamboos (Nkokolosa, personal communication, 2014). Many groups and institutions are involved in tree planting, including CBOs, farmer clubs, area development committees, small-holder farmers, village natural resource management committees, village development committees, herbalists, local development funds, women and youth groups, NGOs and tea estates. As in other countries in the region, it is difficult to estimate survival percentages after planting.

6.3.3. Tree breeding in Malawi

The Forestry Research Institute of Malawi (FRIM), with HQ in Zomba, is one of the operational sections of the Department of Forestry that is mandated to conduct research and development activities. Tree breeding work in the country closely followed the programmes in South Africa, Zambia and Zimbabwe and was initiated in 1965. Initial work was on selecting seed stands in commercial compartments. The first was that of *P. patula* created to meet the seed demand of the Viphya Plantations. This was followed by *P. oocarpa* as it proved to grow well on sites considered marginal to *P. patula*. In the early 1980s*, E. camaldulensis, E. pellita* and *E. tereticornis* were introduced for planting in the drier parts of the country. Table 13 lists some of the seed sources for commercial species. According to Likoswe (personal communication, 2014), most seed stands have been lost through illegal tree felling and some have very low seed production due to old age which makes collection very expensive. Some of the orchards that were established in the 1950s are moribund and some have been destroyed by fires. The seed centre has been relying mainly on imports from Zimbabwe, although there have been concerns of the physiological quality of the seed.

Table 13. List of seed sources of some of the commercial forest plantation trees species in Malawi.

Species	Seed source class*	Year of establishment	Location	Area (Ha)
Pinus kesiya	O	1975	Dedza	4.86
P. kesiya	I	1971	Dedza	4.68
P. oocarpa	O	1969	Dedza	2.41
Eucalyptus camaldulensis	S	1980	Dedza	1.33
E. grandis	S	1978	Dedza	1.7
E. grandis	S	1974	Dedza	1.02
E. tereticornis	S	1992	Dedza	1.87
P. taeda	O	1978	Dedza	1.6
P. patula	P	1978	Dedza	4.67
P. kesiya	O	1983	Chikangawa	2.3
P. kesiya	O	1974	Chikangawa	3.11
P. oocarpa	P	1985	Chikangawa	3.82
P. patula	P	1968	Chikangawa	4.36
P. pseudostrobus	S	1974	Chikangawa	1.34
E. grandis	P	1975	Chikangawa	1.24

*I = identified seed; O=orchard seed; S=select seed; P= provenance

Source: Likwose, personal communication 2014.

Research for other species has been led by international organisations such as ICRAF which has introduced a large number of agroforestry species. Initially, the trials were to evaluate the growth and performance of the species, and gradually provenance trials were established with the objective of selecting the best seed sources. For example, a provenance trial of *Gliricidia sepium* was established as part of an international trials network and the results show that two provenances, namely, Belen Rivas and Monterrico, combined high phenotypic stability and leaf biomass yield across five diverse sites (Australia, Indonesia, Malawi, Nigeria, Zambia) (Nyoka *et al*., 2012). Conversion of the provenance trials of most of the agroforestry species to seedling seed orchards is on-going. However, this type of work is long-term and there are suggestions that national research organisations, such as FRIM, should be responsible. Obviously, the classical breeding strategy used for commercial species may not be applicable for most agroforestry species since the breeding objectives change and the markets for the genetic material are transient. For some indigenous species, ICRAF has initiated vegetative propagation where scions from provenances that produce good fruits in terms of size and sweetness are being collected and grafted onto root stocks. This work has been done for species like *Uapaca kirkiana, Zizyphus mauritiana* and *Sclerocarya birrea*.

6.3.4. Tree seed production in Malawi

Tree seed production is handled by three main players, namely, the National Tree Seed Centre (NTSC) at FRIM, the Land Resource Centre (LRC) in Lilongwe, and ICRAF based at Chitedze Agricultural Research Station. Surveys on tree seed producers and distributors by Pedersen and Chirwa (2005), showed that, apart from these three permanent seed suppliers, there is a large number of NGOs, Government organisations and village groups involved in seed production and distribution. The NTSC has no capacity to meet all seed requirements of the forest industry which has led to a number of players entering into the tree seed business.

All commercial species (pines and eucalypts) are handled by the NTSC. FRIM has a number of seed orchards for most commercially important species (Table 13). However, due to lack of funding, most species are still in the first generation of selection. Most of the seed from the NTSC is sold to concessionaires who replant after extracting timber. The tree breeder based at FRIM is responsible for ensuring that the right site-species matching is done for optimum performance and growth. FRIM is also responsible for training contractors on the importance of using high quality tree seeds. However, some seed orchards are very old and are no longer as productive, and NTSC has been buying seed from Zimbabwe and South Africa (Table 14).

Table 14. Seed importation into Malawi in the past 5 years.

Species	Quantity (kg)	Country
Pinus patula	15	Zimbabwe
P. oocarpa	40	Zimbabwe
P. taeda	20	Zimbabwe
P. elliottii	25	Zimbabwe
Eucalyptus grandis	4	Republic of South Africa
E. grandis	2	Zimbabwe

Source: Likoswe, personal communication 2014.

ICRAF and LRC handle mainly agroforestry tree species. Table 15 lists some of the most common species and the institutions conducting research on the species. For some species such as *F. albida*, ICRAF and LRC collaborate with FRIM in seed collection because FRIM has access to a wide distribution range of the species, including natural forest reserves and national parks. ICRAF has a seed orchard of *G. sepium* and all other species are collected from research demonstration trial and plots on farmers' fields (Pedersen and Chirwa, 2005).

Eucalypts remain the preferred species for planting by farmers and tobacco growers due to their fast growth and excellent firewood, poles and posts. Eucalypts are also being promoted to produce wood energy for curing tobacco. The use of eucalypts by small-scale tobacco growers has increased the value of eucalypt woodlots in the country (also in Zimbabwe and Mozambique). *E. grandis* is in high demand and seems precious to most farmers. The often misunderstood negative effects of *Eucalyptus* on crop yield and water use were mentioned quite often in the discussions.

Table 15. Species focus by the largest three tree seed suppliers in Malawi.

Species	LRC	FRIM	ICRAF
Azadirachta indica	+	+	0
Cajanus cajan	+	0	+++
Calliandra calothyrsus	0	+	+
Faidherbia albida	+++	+	0
Gliricidia sepium	+	++	++
Grevillea robusta	0	0	0
Senna siamea	+++	+	0
Senna spectabilis	+++	+	0
Sesbania sesban	+++	+	0
Tephrosia vogelii	+++	++	+++

Legends: 0 no seed + occasional ++ substantial +++ major

Source: Pedersen and Chirwa, 2005.

FRIM provides the most diverse number of species, including for plantations (eucalypts and pines) and other indigenous species. However, the amount of agroforestry species seed FRIM collect is smaller compared to those collected and distributed by ICRAF and LRC.

Figure 7. Bags of *Tephrosia vogellii* seed delivered for processing at the ICRAF Research Station at Chitedze Agricultural Research Station (photo by C. Marunda, 2014)

Local informal collectors also play an important role in the tree seed supply chain. Most projects involving community tree planting procure seed from local collectors. Most tree projects have a training component on seed collection and handling, and after training "trained entrepreneurs" go out and collect seed. Their main customers are the tree planting projects, LCR and in some cases FRIM. It would appear that the collection and handling of agroforestry tree seeds, is a self-perpetuating system, where NGOs initiate projects and train the communities. Then, local farmers collect the seed and sell to the project or other buyers like LRC, ICRAF and FRIM, who in turn sell, or distribute for free, the seed to farmers. Thus, a free tree seed market is virtually absent as it has been taken over by these three organisations who all buy seed (very competitively) from villagers/collectors from either specific areas (seed sources) or general seed zones (Pedersen and Chirwa, 2005).

While FRIM has a large number of species, their seed prices tend to be higher than that of seed from LCR or ICRAF. This is because FRIM, as a government organisation, has large internal costs compared to local collectors, and most NGOs and LRC prefer local collectors. ICRAF and LRC tend to handle fewer species, but they procure and distribute large amounts of seed.

Since there are several players in the agroforestry and indigenous species seed trade, it is difficult to monitor genetic quality of the seed distributed. The distribution of agroforestry seed of unknown genetic quality has been identified as one of the major constraints to realising the full potential of the species (Nyoka *et al*., 2011). However, good efforts have been made by the many actors who have identified priority species. Traditionally, tree breeding and establishment of seed orchards have been done by government institutions, and there seems to be an expectation that the government, through FRIM, will take up this role. Agroforestry species have been researched and there is now considerable experience in Malawi and indeed the rest of the Southern Africa region. The question to ask is why are the issues of tree breeding, seed orchard establishment and supply of certified seed still bottlenecks? Perhaps the short term nature of funding by donors, and dwindling resource allocation to R&D could be contributory factors. Also, the end uses of the species vary from area to area. Besides, priorities change as projects end and others start. So, any breeding programme may face challenges in setting breeding objectives and maintaining the programme over long periods of time.

The need for formalised seed delivery pathways have been discussed extensively in Malawi (Lillesø *et al*., 2011). As long as there is no formalised genetic quality control through establishment of seed orchards and demonstrating the actual demand of the species (beyond donor projects and government subsidies), any formalised delivery pathway will face challenges. Already, it has been mentioned that if FRIM, for example, establishes seed orchards, then a monopoly of the seed distribution would result making the seed expensive and out of reach for subsistence farmers. While a large number of players in the distribution of seed for agroforestry species may appear confusing, it might be the only way to get the germplasm to the end-users on the ground.

6.3.5 Key findings in Malawi

- Statistics on afforestation and reforestation are difficult to obtain since there are too many players in the sector and the Forest Department does not have enough capacity to monitor such activities.
- While Malawi has seed orchards of commercial species, some of these are old and no longer productive. There is need to rejuvenate the old orchards. The status of most provenance trials also remains unclear, and Malawi might have lost a number of trials through illegal cutting and fires.
- ICRAF has assembled a good genetic resource for agroforestry tree species in Malawi and is contributing significantly to seed production and distribution. ICRAF and LRC appear to have enough capacity to store and distribute the seed. However, the issue of sustainability beyond donor projects still needs to be addressed.
- There is need to control proliferation of tree seed suppliers in the country by setting standards that they must meet to be engaged in the business of seed collection and distribution. FRIM can play a role in setting and enforcing such standards.

6.4. SOUTH AFRICA

6.4.1. Plantations in South Africa

The area under plantation forestry totals c. 1.763 million ha in 2015, i.e. approximately 1.5% of the total South African land area of 122.3 million ha (see Table 1). The commercial forest industry is of considerable economic importance to the country contributing about 0.4 to 1.2 % of GDP. Table 16 shows the plantation areas, the tree types and the ownership. Overall, of the planted areas, 53% is pines, 39% is eucalypts and 8% is wattle (*Acacia mearnsii*). Plantation forests are located mainly in the Northern and Eastern Transvaal, KwaZulu/Natal, Eastern Cape, and Western Cape Provinces, where climatic conditions are suitable, with the largest plantation areas in the Eastern Transvaal (571 000 ha) and KwaZulu/Natal (529 000 ha). Departmental statistics indicate that most land suitable for further afforestation is in KwaZulu/Natal, the Eastern Transvaal and the Eastern Cape. While there is still a net surplus of sector exports over imports, the margin has narrowed by 32% since 1992, and, according to projections, South Africa will soon become a net importer, especially of saw logs (Department of Agriculture, Forestry and Fisheries, RSA, Annual Report, 2013).

Table 16. Plantation area by species and ownership in South Africa.

Species	Private (ha)	Public (ha)	Total (ha)	Private (%)	Public (%)
Softwood	491 746	155 012	646 758	76.0	24.0
Eucalyptus grandis	262 949	36 184	299 132	87.9	12.1
Other gum	213 193	15 554	228 747	93.2	6.8
Wattle	84 808	4 074	88 882	95.4	4.6
Other	4 081	843	4 923	82.9	17.1
Total	1 056 777	211 666	1 268 443	83.3	16.7

Source: Forestry South Africa, 2012.

6.4.2. Main softwood plantation species in South Africa

The main species planted in South Africa is *P. patula* because of its broad environmental and site requirements. It grows rapidly, captures the site quickly and can withstand drought and frost periods. It is widely grown in the Mupamalanga, KwaZulu-Natal and Eastern Cape provinces. The good wood quality makes it suitable for short-rotation pulpwood and long rotation for sawnwood. The other main species are *P. elliottii* and *P. radiata*, with the latter grown exclusively in Western Cape Province. For *P. patula*, there are concerns that the species is becoming susceptible to fungi attack (*Fusarium circinatum, Sirex noctilio*) and many companies have embarked on researching hybrids and trying out new promising species such as *Pinus tecunumanii* and *P. maximinoi*. A number of hybrids are being tested in cooperation with Camcore (Table 17). One of the popular hybrids is *P. elliottii* x *P. caribaea* which has consistently shown good growth and form and field evaluation trials are showing that the *P. patula* x P. *tecunumanii* is showing a lot of promise (Camcore, 2013).

Table 17. Some of the hybrids planted or being evaluated in South Africa

Species	*P. patula*	*P. elliottii*	*P. radiata*	*P. tecunumanii*	*P. greggii*	*P. caribaea*
Crossed with	*P. pringlei* *P. greggii* *P. tecunumanii* *P. oocarpa* *P. elliottii*	*P. tecunumanii* *P. caribaea* *P. maximinoi* *P. taeda* *P. greggii*	*P. patula*	*P. oocarpa*	*P. maximi noi*	*P. tecunumanii*

Source: Camcore, 2013.

6.4.3. Main hardwood plantation species

Hardwood plantations in South Africa, like in most of the countries in the region, depend on eucalypts for sustainable and productive industrial forests. Increases in productivity and resistance to pest and diseases have been achieved through research programmes such as site-species matching and maintenance of a broad genetic base to reduce stress caused by drought, pests, diseases, frost and snow. *E. grandis* is the most widely planted species. Due to increases in demand for hardwoods for pulp, there has been expansion of tree planting in cold climates with snow fall in South Africa. *E. grandis* is one of the least tolerant species to snow (Gardner and Swain, 1996). To address this challenge, the research and development sector in the country started introducing other *Eucalyptus* species (Table 18). These species are cold tolerant and have good wood properties, resistance to diseases and pests that would normally attack *E. grandis*. Inter-specific *Eucalyptus* hybrids are also being developed to combine desired traits of two species, increase the performance of the trees in areas which are marginal for the parent species and exploit hybrid vigour (SAPPI, 2006).

In recent years, areas planted to cloned hardwood species have increased, especially in the KwaZulu-Natal province. The statistics on areas planted with pure eucalypts (*E. grandis*) and clonal material (grandis hybrids) is difficult to estimate as most plantation owners confuse the two and usually record them as pure species (Forest Economic Services, 2012). The planting of hybrids has its own disadvantages. For example, there are concerns that clonal hybrids may lead to a narrowing of the genetic resource base, creating conditions perfect for the spread of diseases and pests (Harwood, 2014) and the costs and labour for raising propagation material may be prohibitive (Griffin, 2014).

Table 18. *Eucalyptus* species and hybrids introduced in South for planting on cold sites prone to frost and snow

Genotype	Commercial species
Cold tolerant	*Eucalyptus bagjensis, E. benthami, E. macurthurii, E. nitens, E. dunnii*
Temperate	*E. grandis* x *nitens*
Sub-tropical	*E. henryii, E. grandis* x *urophylla*

Source: Mondi and CAMCORE.

The other commercial species widely grown in South Africa is *Acacia mearnsii* (wattle). It is mainly grown for its tannins found in the bark which are used for treating leather. The wood is suitable for charcoal, firewood and for building purposes. The species is widely grown on poor sites (SAPPI, 2006) and has the advantage of enriching soil through nitrogen fixation (Brockwell *et al.,* 2005).

6.4.4. Reforestation rates in the commercial forestry sector

The trends in commercial forestry plantings in South Africa (Figure 8) indicate that there has been a marked decline in both softwood and hardwood planting since the mid-1990s, and that there has been an increase in the areas for pulpwood compared to areas for saw-logs and mining timber (DAFF Annual report, 2013). Land for extension planting is becoming scarce, and temporarily unplanted areas (TUPs) have become permanently unplanted areas due to strict reforestation permits (water and conservation permits) and privatisation of former state forests. Due to the restructuring of the forest sector and the gap left when government exited forestry, new players (B and C forest plantation categories to be transferred to communities) who focus on harvesting for short-term returns and less on tree establishment and management filled in the gap. The issue of underlying land claims has not been fully addressed for Category A plantations (forest plantations transferred to the private sector) resulting in the use rights of the lessee (private sector) being challenged. This constellation of factors seem to point to a decline in the level of tree planting in South Africa and could lead to future deficits in timber supply, especially sawlogs (DAFF Annual report 2013; Forestry South Africa, 2014).

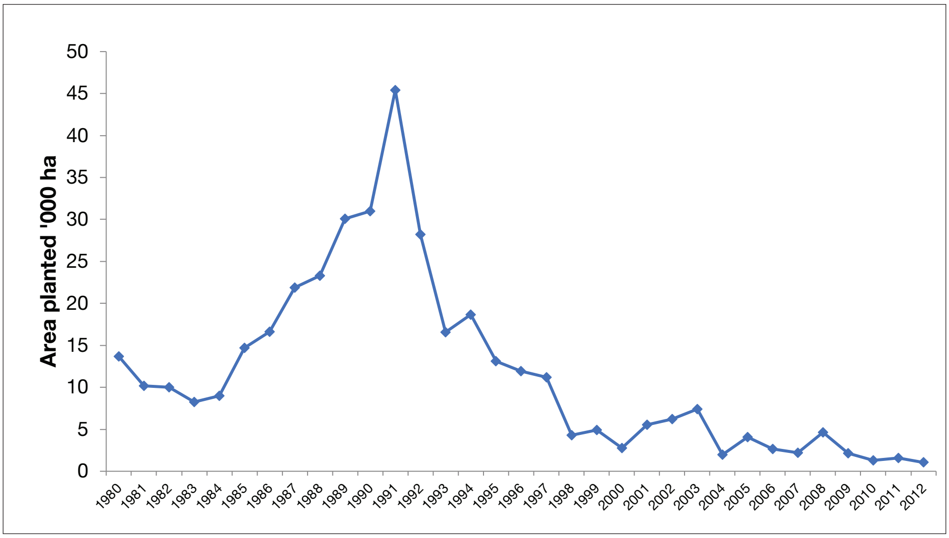


Figure 8. Declining trends in new afforestation rates from 1980 to 2010. The sharp decline after 1990 coincides with the shift in policy requiring permits for tree planting, water regulations and black economic empowerment.

Plantation forestry is regarded as a water-consuming land use; therefore permits are required to expand the area under plantations. Other factors include the privatisation of many former state forests, which has resulted in private sector lessees favouring shorter-term returns via pulpwood use over longer-term returns from saw-logs, as well as the state's poor upkeep of Category B and C plantations, which has reduced their productivity. One subsector that has already been affected by the decline in timber supply is sawmilling, with the number of sawmills decreasing from 115 to 90 between 2004 and 2010 (DAFF, 2013). There has been a marked increase in the area of plantations for pulpwood as compared to the area for saw logs and mining timber.

Representatives of Forestry South Africa say the government has failed to act on its commitments to plant about 100 000 ha in the Eastern Cape and to provide grants for small growers. To date, only about 2 000 ha have been planted and no fiscal commitment had been availed (Forestry South Africa, 2012; Modise, personal communication, 2014). While it is clear that the private sector has good management capacity and has ushered in efficiencies across the value chain, the DAFF must still play a big role to ensure adequate levels of investment, especially for longer-rotation timber/saw log plantations. This would mean putting in place policies that would encourage secure tenure and easy access to land. The industry which is responsible for most of tree breeding has also to respond to this challenge by availing adequate species and germplasm suitable for long rotations.

The implication of the decline in reforestation rates, projected deficits in timber supply and the shift towards short-rotation pulpwood means that South Africa may need to increase its rates on tree planting using germplasm and management techniques suited for long-rotation timber. Most companies are focusing on short-rotation trees for increased fibre gain per given area. South Africa appears to have the germplasm it would need to plant more long-rotation plantation, but this has to be balanced with economic and profitability issues. Table 19 shows the new areas planted since 2005. The trend is that more areas are being planted with hardwood species compared to softwoods. These areas are marginal to traditional species such as *E. grandis*, and the implication is that new species should be tested for such sites.

Table 19. New afforestation areas by species from 2005/6 to 2011/12.

Year	Softwood (ha)	Hardwood (ha)	Total (ha)	Softwood (%)	Hardwood (%)
2005/06	707	1 928	2 635	26.8	73.2
2006/07	418	1 780	2 198	19.0	81.0
2007/08	648	3 993	4 641	14.0	86.0
2008/09	742	831	1 573	47.2	52.8
2009/10	210	908	1 118	18.8	81.2
2010/11	395	1 178	1 573	25.1	74.9
2011/12	336	709	1 045	32.2	67.8
Totals	3 456	11 327	14 783	23.4	76.6

Source: Forestry South Africa 2012.

There is a growing trend towards out-grower schemes in the growing and management of plantations. There are currently over 20 000 small growers managing over 40 000 ha. Most major companies are outsourcing their forest operation to contractors to save money. A key question is how best to support the communities who have received ownership of plantations via the land restitution programme, and new players in the sector in terms of accessing good germplasm and how to build flexibility to face the challenges of increasing rates of plantation establishment and planting long-rotation trees for saw-logs and mining timber.

The conundrum facing the South Africa forestry sector is complex. The sector has a huge resource geared towards supplying short rotation pulpwood. There are restrictive planting permits meaning that increased productivity can only be achieved on limited areas. Temporarily unplanted areas are increasingly becoming permanently unplanted areas, and category B and C plantation are poorly managed. R&D by the private sector is geared towards fibre gain (pulpwood). On the other hand, there are projections that the country could face a saw-log deficit, and, if this is to be addressed, there is need to come up with enabling policies to encourage afforestation and reforestation for sawlog production.

The Government and the forest industry are concerned about the future supply of wood in South Africa. The prevailing view is that a substantial increase in the afforested area in South Africa is needed. Consumption per person will increase as the economy improves. This demand will be mainly for pulp and paper and timber for constructing houses (e.g. the Reconstruction and Development Programme). The Forest Industries Association estimates that an additional 16 million m^3 of wood per year will be needed in 2020 to fill the gap between the expected demand and the supply from the currently afforested land at that time.

Since tree breeding techniques and other general improvements in forest management can increase the yield per unit area from current afforested areas, the forestry sector needs to look at management options for long-rotation plantation for supply of sawlog and mining timber. Additionally, some South African forestry companies are investigating new afforestation initiatives in other countries of the southern African sub-region, such as Angola, Malawi, Mozambique, Zambia and Zimbabwe, and would need to invest in tree breeding or procure suitable germplasm for these external ventures.

6.4.5. Tree germplasm supply in South Africa

Due to the restructuring of the forest sector, seed supply in South Africa is largely handled by the private sector and the suppliers are specialised in commercially important pine and eucalypt seed. There is a shortage of seed for non-commercial species and in most cases requests are not met. The Department of Forestry (out-grower scheme section) receives quite a lot of requests for seed for non-commercial species, but there is no capacity to meet the increased demand (Modise, personal comm., 2014).

South Africa participated in the SADC Tree Seed Centre Network and was supported by CIDA to strengthen its seed production. The plan was to support DAFF establish a seed centre to supply seed to non-commercial tree growers. Over the years, and due to institutional changes, the seed centre functions were given to the private sector in 2000 since seed trading was not considered a core function of government (Modise, personal communication, 2014). The result of this change is that there is now a gap in the supply chain for non-commercial species and local communities, NGOs and other tree growers (e.g. urban councils) are finding it difficult to get seed for general planting and aesthetics. Private seedling nurseries are the major suppliers of non-industrial species and most species are sold for ornamental purposes. This means that for the majority of the rural people who would normally depend on the DAFF to supply seed for community tree planting projects, they are finding it difficult to procure seed.

Most private companies have their own capability to conduct tree breeding and research and produce their own seeds especially for commercial species such as pines and eucalypts. For example, SAPPI has its own seed centre that produces and supplies seeds of a number of species including; *Acacia mearnsii, Eucalyptus dunni, E. grandis, E. macarthurii, E. nitens, E. smithii, E. badjensis, E. benthamii, E. dorrigoensis, E. pellita, E. saligna, E. urophylla and E. viminalis* and *Pinus elliottii, P. patula, P. taeda, P. kesiya, P. greggii, P. caribaea* and *P. tecunumanii*. Pelletised eucalypt seed is also available at an additional cost. Seed is available in the following categories based on the level of genetic improvement:

- *Select:* Seed production areas based on domesticated or provenance seed excluding best families;
- *Superior:* First generation seed orchards (selected parents);
- *Elite:* Selective family harvest of first generation orchards (tested parents); and,
- *Advanced:* Advanced orchards, including controlled pollinated seed that will rival current clonal planting stock.

Collections of indigenous species are done by private nurseries for ornamental purposes. Indigenous species are usually planted as ornamentals on private homes and used by city councils for landscaping (Johannesburg is one the most forested cities in the world!). However, there are also tree planting activities done to rehabilitate degraded forests. For example, planting of selected natural forest species such as *Podocarpus falcatus, Podocarpus henkeli* and *Ptaeroxylon obliquum* planted in mixtures with *Pinus halepensis*. In KwaZulu-Natal, dunes are actively rehabilitated after mining for heavy minerals using *Acacia karroo* as the main species. Many other species are established under the *A. karroo* nurse stands (Geldenhuys. 2002). Seeds of such species are collected as and when needed.

6.4.6 Key findings in South Africa

- South Africa is projecting a huge sawlog deficit in the near future and the gap can be filled by increasing rates of afforestation. This will certainly drive up demand for appropriate germplasm and new species or provenances of existing species since the new areas of planting might be marginal to existing improved species.
- Traditional breeding objectives in South Africa have focused on pulp yield (fiber gain), but this may have to change as long-rotation sawlogs becomes a priority product.
- There are, however, restrictions on areas for afforestation and same harvested areas are being left as TUPs until land claims have been solved. This would mean that companies and other growers have to maximise productivity and profitability on limited land. This requires growing genetic material that is more productive per unit area.
- The structural reforms in the DAFF resulted in the seed centre functions being handed over to the private sector. This meant that DAFF, through its extension directorate, is no longer able to supply seed, especially for community tree planting projects. There is need to improve the supply of non-commercial tree species.
- The private sector has a lot of in-house capacity to conduct research and meet its own seed needs. Participation of most companies in Camcore activities is ensuring good access to a broad genetic base. Most companies are also investing in clonal hybrids for both pines and eucalypts.

6.5. MOZAMBIQUE

6.5.1. Plantations in Mozambique

It is estimated that Mozambique has about 7 million ha of potential area for afforestation with fast growing species in five of the ten provinces, *viz.* Sofala, Manica, Zambezia, Nampula, and Niassa provinces (DNFFB, National Directorate for Forestry and Wildlife, 2005). Coetzee and Alves (2005) suggested that at least 3 million ha in these five provinces could be converted to plantations. Much of this area could be available where land, water, resources protection, population density, land-use and conservation are not considered to be restricting factors for the production of timber trees. The programme is targeting to plant 1 million ha under commercial species creating 100 000 jobs and generating USD 20 billion in the next 20 years (Coetzee and Alves, 2005).

Currently, Mozambique has between 50 000 and 62 000 ha (FRA, 2010) of plantation forests and this figure is rapidly increasing as private companies continue planting commercial pines and eucalypts in the northern part of the country.

Table 20: Areas of plantation forests in Mozambique in hectares.

Species	Up to 1975	1986	1989 MONAP*	1992/95	2000/2005
Pines and Eucalypts	16 438	22 339	17 981		26 100
Others		18 120			20 100
Casuarina	2 873	1 209	1 209		4 000
Others		983			
Total	19 311	42 651	19 100	38 000	50 200

Source: Coetzee and Alves 2005

*MONAP = Mozambique Nordic Agricultural Programme

A number of companies are forging ahead with new plantings in the northern part of the country, although they are constrained by difficulties in securing land from the communities. The government is actively promoting the private sector and foreign investment in establishing and managing forest resources. So far, 24 000 ha of pine and eucalypt plantations have been established. The figures in Table 20 above may be gross under-estimations of the total land under forest plantations in the country.

6.5.2. Commercial species in Mozambique

The first exotic species introduced in Mozambique were *Eucalyptus tereticornis, E. rostrata* and *E. robusta*. These were introduced as arboretum plantings. *Casuarina equisetifolia* was also introduced for sand dune fixation. Other species introduced included pines, *Araucaria cookie, Cupressurs* species, *Melaleuca leucadendrum*, *Grevillea robusta*, *Cassia siamea, Delonix regia, Jacaranda mimosifolia, Spathodea campanulata* and *Tabebuia rosea*.

A few of these species made it into the list of commercial species and the following species were used in the establishment of forest plantations: *E. grandis/saligna, P. patula* and *C. equisetifolia. E. tereticornis* was introduced in the 1950s but the species performed poorly. This led the Forestry Department to establish a provenance trial of this species and *E. camaldulensis* in Michafutene. An analysis of the trial by Chamshama *et al.* (1999) recommended four provenances for general planting in the country, *viz.* South of Helenvale, West of Mareeba, Kennedy River/North Lakeland and Cooktown, all from Australia. This material has formed the progenitor of the germplasm being planted in Mozambique to date. A number of commercial species were also introduced in the Manica province, including *P. patula*, *P. elliottii, P. taeda, P. caribaea* and *P. kesiya,* mainly based on research going on in neighbouring Zimbabwe.

The opening up of the northern part of the country to plantation development has created the need to introduce new species, clones and hybrids best suited for the area. Previous research had focused on species suitable in the Manica province, largely based on research and seed sales from neighbouring Zimbabwe. The private companies have realised that there is not enough information to guide the massive afforestation programmes in terms of species choice and other silvicultural issues, such as site-species matching, clonal development, native commercial species development and many other scientific applications (Kwesha and Mudekwe, personal communication, 2014). Many forest research trials that could be utilized for this purpose have been lost in the past and need to be re-established. Thus, private companies that are establishing plantations are using information from other parts of the world, and collaborating with Camcore to build a genetic base for pine and eucalypt species. They are importing seed from different parts of the world. The main sources of seeds are Zimbabwe, South Africa, Uruguay, Brazil, Honduras, Australia and Tanzania, as well as Indonesia for teak. Some of the seeds have been used to establish plantations and some have been planted in trials (Figure 9, 10 and 11). The plantations in the Niassa province in the North started about 2004/05. Prior to that, only Ifloma in Manica were involved in commercial timber plantation development. The major forest companies involved in forestry in Niassa were Chikweti Forests of Niassa with its subsidiaries Tectona and Ntacua in Zambezia, Florestas de Niassa, New Forests, Green Resources and Uruguay. The major species grown are shown in Table 21.

Table 21. Exotic species grown in Mozambique

Pines	**Eucalyptus**	**Teak**
P. maximinoi, P. tecunumanii, P. oocarpa, P. caribaea var. hondurensis, P. patula, P. taeda	*E. grandis, E. urophylla, E. urograndis, E. pellita, E. dunnii*	*Tectona grandis*

Mudekwe, personal communication, 2014.

P. patula, P. taeda and *E. grandis* were the main species previously grown in various parts of the country by the government of Mozambique. The performance of these species in Niassa Province was not very promising and after some field tests, *P. maximinoi, P. tecunumanii, P. oocarpa, P. caribaea, E. urograndis, grandis* and *urophylla* became the major species for plantation development. Research seed-lots have been procured through their Camcore membership. The objective of the introduction of the research seed-lots is to assess the performance of pine, eucalypt, teak and hybrid material in the local environments.

Figure 9. 2 year-old trial of P*. tecunumanii* and *P maximinoi* near Lichinga, Niassa Province, Northern Mozambique (photo by C. Marunda, 2014).

Figure 10. Three-year old pine plantation showing outstanding growth, Lichinga Niassa Province, Northern Mozambique (photo by C. Marunda, 2014).

Figure 11: Demonstration plots of various Eucalypt species near Lichinga. *E. urograndis* and *E. pellita* were performing very well (photo by C. Marunda).

While seed of different species and quality could be obtained from various sources, there was an increasing problem of getting seed material across borders. Phytosanitary requirements were, and are, increasingly becoming restrictive. Such problems emanated from the fear of spreading pests and diseases. In addition, cost of the seed, wherever it was available, was becoming prohibitive. As such, most forest companies are starting to embark on programmes to develop seed stands and seed orchards, as well as developing tree breeding and tree improvement strategies, to be self-sufficient.

It is acknowledged in Mozambique that a collaborative approach to research on tree breeding, seed orchard establishment and exchange of scientific information on silvicultural operations is an attractive proposition. Efforts to engage the Government through DNFFB or the Instituto de Investigação Agrária de Moçambique (IIAM) for support are underway.

Most forest companies recognise that genetically improved seed from orchards will deliver more reliable seed, good seedling performance and improved plantation productivity. All companies have been importing seed of known origin, and this gives them an opportunity to select seed-lots that are genetically adapted to the conditions prevailing in the growing areas. This ensures that further productivity gains can be realised. A strategy that can be built in the system is to use trial data to guide the purchase decisions for suitable commercial seed (bulk or family) for plantation development in the short to medium term. A further strategy will be for the companies to develop seed orchards of their own, with material selected from the network of trials being established.

Seed production/procurement options may include:

- conversion to seed orchards of the trials established in Mozambique that are stocked using some known provenances;
- the partial or full conversion of existing trials to seed orchards through culling;
- the development of joint seed orchards with other companies or countries (e.g. Zimbabwe for *P. caribaea*, *P. tecunumanii* or *P. maximinoi*); and,
- companies will continue buying seed on international markets in the short to medium term as guided by information from the provenance/progeny trials in Mozambique.

It should be noted that the material already assembled in Mozambique underpins a long-term strategy where the best performing species, provenances and families would be used in a breeding programme to make additional gains on plantation productivity in the country.

6.5.3. Tree seed production in Mozambique

The restructuring of the forest sector saw the Centre Experimentacao Florestal (CEF) being moved to IIAM. This has resulted in less attention and investment in forestry research and the capacity of the seed centre to produce tree germplasm has diminished. Private companies are importing their own seed. Discussions with private companies in the northern part of the country revealed that they were not aware of the existence of the seed centre in the country. The lack of direct contact has been attributed to the long distances and the fact that the TSCN is housed under agricultural research. The seed centre could play a crucial role in assisting with importation and documenting information on all imported seed-lots and help keep records for future reference (Alima Issofu, personal communication).

Most companies in Mozambique do not have the capacity to produce their own seed and have historically relied on purchasing seed from a number of sources, e.g. Zimbabwe, South Africa, Australia, Argentina, Chile and Brazil. Tables 22 and 23 show lists of species imported and source countries. The introductions represent a comprehensive list of species and provenances that can form a good base for a targeted tree breeding programme as described in the previous section.

Seeds, mostly of pines, were also imported from Zimbabwe, but there were concerns for their physiological quality as some seed-lots had very low germination capacity (recurrent power cuts in Zimbabwe meant that the cold rooms were not fully functional and this resulted in seed losing viability).

NTSC collects seeds of *E. camaldulensis* and *E. tereticornis* from select stands for distribution to communities for the establishment of woodlots. Discussions with CEF and NTSC staff revealed that the seed centre is concentrating on the supply of indigenous species that are collected on an opportunistic basis. Agroforestry species are in short supply as there have not been many agroforestry trials. The most widely planted agroforestry species is *Leucaena leucocephala.* Major plantations are located in Maputo, Gaza, Manica, Nampula and Cabo Delgado Provinces using K-28, K-8, Malawi and local provenances. The species has mainly been used for fodder and fuel wood. About 1 000 ha are *Leucaena* stands (Silva-Ruas and Rombe, 1994). Such trials are the main sources of seed collected by the seed centre in Mozambique.

Another popular species collected is *Casuarina equisetifolia* which is planted along the coastline for sand dune stabilisation. Most timber species are under pressure from commercial logging to supply overseas (e.g. China) and local markets. For this reason, CEF surveys and collects seed of the following key species for research and conservation: - *Dalbergia melanoxylon, Milicia excelsa, Androstachys johnsonii, Khaya nyasica, Guibourtia conjugata, Pterocarpus angolensis, Spirostachys africana* and *Afzelia quanzensis* (da Silva et al., 1995). There is a lack of information on the present status and the level of mechanisms adopted to protect these threatened forest species in Mozambique.

Most of these species are harvested for timber by concessionaires. There is an expectation that contractors/concessionaire plant seedlings of the species that they harvest, but surveys by Savcor Indufor Oy (2005) on 25 companies in Sofala show that only seven produced seedlings of native species for reforestation in cooperation with local communities where nurseries are located. These are low numbers considering that almost 50% of the companies operate concessions, the management plan of which include reforestation activities. There is an urgent need to develop a programme on domestication and management of such species to guarantee their conservation and sustainable utilization. The DNNFB, CEF and NTSC could play a leading role in availing germplasm to the companies and monitor that afforestation is actually taking place.

Table 22. List of pine species and provenances introduced in northern Mozambique.

Species	Provenances
P. elliottii	Stapleford reserve, Muguzo Forest Research Station, Australian origin, South Africa origin, Honduras origin,
P. tecunumanii	Muguzo Forest Research Station, Honduras origin, San Rafael-Nicaragua, Jocón – Yoro, Hondura,s El Rodeo - Comayagua, Honduras, Villa, Santa - El Paraiso Honduras, Yucul - Repca. De Nicaragua
P. kesiya	Stapleford Reserve, South Vietnam, South Africa
P. taeda	Stapleford Reserve
P. patula	Stapleford Reserve ,South Africa, Malawi Chizengu,
P. pseudostrobus	
P. maximinoi	Tatumbla, Dulce Nombre de Copán, Siguatepeque, Las Botijas, Santa Bárbara, Lepaterique
P. caribaea var. hondurensis	Dulce Nombre de Culmi, El Venado, Ojo de Agua, San Jerónimo, San Jerónimo, Siria, Santa Cruz de Yojoa, Tierra Blanca, Santa Bárbara
P. oocarpa, P. tecunumanii, P. maximinoi	CAMCORE seed

Source: Kwesha and Mudekwe, personal communication

Table 23. List of some of the eucalypt species introduced in northern Mozambique

Species	Provenance	Country
E. pellita	Bupul	Indonesia
E. pellita	Refocosta	Colombia
E. pellita	Sappi (Bulk)	South Africa
E. brassiana	PT Sumalindo	Indonesia
C. henryi	Mondi	South Africa
E. grandis	Merensky	
E. grandis, E. camaldulensis	Kenya	Kenya
E. grandis x E. camaldulensis	Anhembi IPEF	Brazil
E. urophylla x E. grandis	Anhembi IPEF	
E. grandis	Botucatu IPEF	
E. urophylla	Piracicaba IPEF	
E. urophylla x E. grandis	SKCV	Venezuela
E. urophylla	SKCV	
E. longirostrata	Sappi (Bulk)	South Africa
E. grandis	Chikweti	Mozambique
E. major	Brooweena	Australia
E. major	27K SE Gympie	
E. major	Blackdown Tableland	
E. propinqua	Coffs Harbour	
E. propinqua	Near Coffs Harbour	
E. propinqua	Taylors Arm	
E. propinqua	Unumgar	
E. punctata	Wingello	

6.5.4. Key findings in Mozambique

- Mozambique has a very large afforestation programme that has so far introduced a lot of pine and eucalypt species.
- There is no coordinated tree breeding and germplasm supply for commercial and non-commercial tree species.
- The wide range of species and provenances offer Mozambique a good base to initiate a breeding programme. The programme could be a joint venture between companies and the government.
- Private companies can pool resources and form a cooperative research unit that can partner with CEF and IIAM, and form joint membership of Camcore.
- The Seed Centre is isolated from the main centres of plantation development especially in the north. There is need for the centre to actively engage with the companies when it comes to importation of seed-lots.
- There is need to support the replanting of indigenous species after harvesting. The tree seed centre could assist the programme by monitoring seed collections from trees during felling and make sure that seeds are used to raise seedlings to be planted on harvested areas.

6.6. SWAZILAND

The first species to be commercially planted in Swaziland was wattle (*Acacia mearnsii*) introduced in the early 1880s. Subsequently, pine and eucalyptus trees were introduced as the main plantation species. Pine species include *P. patula, P. radiata* and *P. taeda*, covering about 80 % of the planted area. *Eucalyptus* species are mainly *E. saligna* and *E. grandis*, covering 20 % of the planted area. The total plantation area is about 161 000 ha, mainly under large corporations.

The Forestry Department has a strategy in place for the seed centre (Gamedze, personal communication, 2104). Since the SADC TSCN network project ended in 2000, there has not been any investment in the tree seed centre. There is no adequate personnel and equipment.

The major forest companies procure their seed from South Africa or from their own seed orchards. The seed centre could play a leading role in procuring seeds of indigenous species for distribution to communities. The natural forests in Swaziland are under threat from over-exploitation, especially in rural areas, despite the fact that of the Southern African countries, Swaziland is the only country that recorded positive expansion of forest cover (see table 1). This is due to the good management practices in the private commercial forests and the expansion of wattle forests which are actively promoted by the Forestry Department as important sources of fuelwood, wattle bark, construction and mining timber. The forestry extension section of the Forest Department promotes tree planting by communities and schools through provision of free tree seedlings. The seed centre could play a significant role in collecting a diverse range of species.

6.7 MADAGASCAR

Madagascar has about 349 500 ha of pine and eucalypt plantations. Eucalypts (mainly *E. robusta*) cover about 47 %. Pines (mainly *P. kesiya* and *P. patula*) cover about 31 %. Other broadleaved plantations cover about 17 %, while Acacias (*A. mangium*) covers 3 % and *Casuarina equisetifolia* covers 2 %. Some of the trees are planted by foresters and farmers, while others have become invasive on their own accord. Despite the deforestation trend, tree cover is increasing in some parts of the country, largely through introduction of (non-native) species. This has been achieved through raising a number of fast growing short lived tree species (e.g. *Acacia. mangium*) on degraded areas to create a canopy which shades off competing vegetation. When the trees start dying out, the natural colonisers from nearby forest will slowly take over (Manjaribe *et al.,* 2013). Madagascar has also been very successful with planting of eucalypts in degraded areas (Box 2).

Box 2. The Madagascar success story using exotic germplasm.

> On the tablelands around Antananarivo in Madagascar, there are 100 000 ha of *Eucalyptus robusta*. These plantations were established 50 to 100 years ago, almost entirely on small-holdings. They are very much part of the local economy and the charcoal they produce supply the city of Antananarivo with most of its domestic and industrial energy needs. They also provide thousands of jobs in hundreds of small charcoal-making and transport enterprises. Most of these plantations are now managed as coppice on a three-year rotation.

Source: Coetzee and Alves, 2005.

6.8. BOTSWANA

Botswana has just about 1 000 ha of plantations, mostly *E. camaldulensis* and *E. tereticornis*. In terms of tree breeding, the only work that was done was screening and provenance trials of species like *Eucalyptus*, *Leucaena leucocephala* and *Atriplex nummularia* (old man's salt bush). Research on indigenous species focuses on fruit trees such as *Sclerocarya birrea* subsp. *caffra*, *S. cocculoides*, *Azanza garckeana* and *Vangueria infausta* (Mutakela, 2001). The Botswana Tree Seed centre was established under the SADC TSCN project in 1998 and supports tree planting activities by supplying seeds to households and communities for home nurseries and urban landscaping.

6.9 NAMIBIA

Namibia has no recorded plantations. A survey by Kamwi *et al*. (2001) showed that there were about 68.2 ha planted, mainly *E. camaldulensis* and *E. tereticornis*. The growth of the plantation was very slow and this was attributed to the poor soil fertility and lack of water. The growth rate of the coppices was faster than the growth of trees originated from seedlings. Because of the unfavourable site and climatic condition, there is no significant planting of trees in Namibia.

The Directorate of Forestry also participated in the SADC Tree Seed Centre Network Project. Seeds of indigenous trees and other plants were collected from natural populations, tested for germination and then distributed by the Directorate of Forestry to private nurseries and community projects. Protocols for handling seed of some indigenous forest species have not been developed and the quality of the seed is not assured, partly because there is no official seed testing laboratory which monitors and provides technical back-up to the tree seed laboratory. Furthermore, research on forestry seed issues has not been given adequate support (National Agricultural Support Services Programme, 2001).

6.10. ANGOLA

Angola has about 150 000 ha of exotic plantations, mainly *E. saligna, E. grandis, E. rostrata, Cupressus lusitanica* and *P. patula* (FAO, 1996). *Eucalyptus* is the main genus planted for timber, fuelwood and pulp. The major species are *E. saligna* (maximum mean annual increment of 37 $m^3 ha^{-1}$ attained at 22 years of age) and *E. grandis* (MMAI of 25 $m^3 ha^{-1}$ at 28 years) (Delgado-Matas and Pukkala, 2011).

6.11 LESOTHO

Tree planting in Lesotho started in the 1800s with the introduction of exotic species such as *Eucalyptus globulus* (blue gum), Oaks, Acacias, Poplars, Pines and Willows. In 1972, the Government of Lesotho established the Forestry Division for development of forest plantations of exotic tree species. The objectives of the plantations are to provide sustainable supplies of forest produce, while at the same time rehabilitating degraded areas (Chakela and Seithleko, 1995). There are currently 478 forest reserves and government owned plantations covering an area of 10 000 ha (Mokuku, 1997). Lesotho also participated in the SADC TSCN projects. Currently the Seed Centre is not fully functional.

7. Regional analysis and Recommendations

7.1. DECLINE IN INVESTMENT IN FOREST RESEARCH AND DEVELOPMENT

Traditionally, research on species introduction and germplasm deployment has been undertaken and funded by respective government forestry departments in the countries. During the past century, a plantation resource base, mainly of exotic species (pines, eucalypts and acacias) was established in the region, contributing significantly to national economies. Over the years, investments by governments in forestry research have declined. Reasons for the decline include:

- perceived declining contribution of the forest industry to the national economy;
- restructuring of the forestry sectors resulting in reduced government involvement;
- privatisation of government commercial forest plantations, thus breaking the umbilical link between research and practice;
- increased international ownership through participation of well-resourced international institutions, resulting in governments abdicating some of their functions; and,
- cost cutting and inadequate recognition by the forest industry of the importance of research and innovation for growth and sustainability.

There has also been a significant brain drain in the region resulting in the loss of capacity and skills in tree improvement and germplasm production. New models of cooperative research that brings together the industry, governments, countries and regional organisations need to be formulated. Information sharing through joint analysis of species performance, germplasm exchanges and setting up MTA to ensure information sharing can contribute to sustained productivity and profitability of forestry. Governments can play a pivotal role in ensuring that policies and strategies are spread as widely as possible, so that the importance and benefits of the industry are better understood. Forestry Departments can play direct facilitation roles in ensuring a coordinated effort and linkages with the industry.

7.2. PROJECTED TIMBER SHORTAGES AND BACKLOG IN TREE PLANTING

From the preceding analysis, it is clear that there are concerns that the region could face a shortage of timber, especially sawlogs. This, coupled with a growing backlog in tree planting, a finite plantation forest resource, potential negative impacts of climate change, and threats of diseases and pests, imply that there is an urgent need for the region to address SFM issues. One approach will be to recommend best strategies to maximise genetic gain by matching genotypes with production environments and ensure immediate adoption of results into selection and deployment programmes of all species planted. There is also an expectation of the risk of plantation failure or suboptimal performance due to changed site conditions as a result of climate change and decline in soil fertility. The region must work collaboratively to ensure that the risk of reduced species performance is minimised across the range of environments and site conditions.

7.3. COMMERCIAL TREE SPECIES

The southern Africa region has had a long history of exotic species screening, provenance testing, and selections for improved productivity. From the analysis, it is quite evident that the region has assembled unique forest genetic resources that are being used now and in the future. However, individual countries are at different levels of sophistication in terms of their breeding initiatives and programmes. South Africa has a very advanced breeding programme, largely driven by the private sector with support from government. Tree breeding research in Malawi, Zambia and Zimbabwe is done by government institutions, and the benefits of the research are deployed to the industry as improved tree germplasm. It is clear that there is a lot of seed exchange and trade between countries.

Table 24 shows a matrix of species by country and illustrates the common species planted and with definitive tree breeding efforts across the Southern Africa region. The matrix provides a basis for potential collaborative work. *P. patula* has been the default species for planting in the high altitude cool areas, but it is gradually being replaced by *P. tecunumanii* and *P. maximinoi*. These two species have proved to outperform *P. patula* (Nyoka, 1994). There is currently a shortage of seed for these two species in the region and the seedling seed orchards established are still very young (e.g. in Zimbabwe). However, there is some evidence that the species are shy-seed producers, so there is need for more research to identify the best sites for seed production (Nyoka and Tongoona, 1998). Other promising species are *P. oocarpa* and *P. caribeaea,* especially on marginal sites. Hybrids of *P. patula* x *P. tecunumanii* are promising and have been tried extensively in South Africa and, more recently, in Mozambique under the Camcore programme. The country-species matrix provides a framework for potential collaboration and exchange of seed between countries.

Trials and plantations of the exotic species throughout southern Africa will be particularly valuable to assess the effects of climate change on growth, form characteristics and secondary effects such as pests and diseases triggered by changes in climate. The information will determine the extent to which we can use genetic selection to mitigate some of the predicted negative effects on timber, other products and environmental services from the genetic resources thus far assembled in the region. It can be commended that a platform be created to use the current tree growth information in the region to model the likely impacts of climate change on tree survival and growth.

Eucalypt species are the most important ones planted in most countries for the supply of wood for construction, fencing poles, pulp-wood and firewood. Other eucalypt species known to be tolerant to drier and cold environments are being tested in South Africa to expand the hardwood plantation resources. Other species or provenances that have never been tried before need to be tested at a regional level to minimise the threats posed by emerging pests (bronze bug, red gum lerp psyllid and blue gum chalcid). This calls for an assembly of a broader genetic base of several species. Many small out-grower farmers plant eucalypts as the first choice species. The impact of pests could be devastating to people's livelihoods and will inevitably result in increased deforestation. This could present a possible area of cooperation between countries which depend on these species for rural afforestation programmes.

Table 24. Country-species matrix for the most commonly planted commercial species. The numbers in parenthesis shows the priority species (not ranked).

Species	**Countries**									
	Ang	**Bot**	**Les**	**Mad**	**Mal**	**Moz**	**SA**	**Swa**	**Zam**	**Zim**
P. caribeaea (6)	+		+	+++	+++	+++	+++	+++	+	+++
P. elliottii (5)				+	+	+	+	+	+	++
P. kesiya				++				+	+++	
P. greggii							++			+
P. maximinoi (2)					+++	+++	+++	++	+	+++
P. patula (1)	+			+	+++	+++	+++	+++	++	+++
P. oocarpa (4)					++	++	+		+	+
P. taeda (7)					+	++	++	++	++	++
P. tecunumanii (3)					+++	+++	+++	+++		+++
P. radiata							+			
P. hybrids(8)					+	+++	+++	++		++
E. camaldulensis (9)	++	+++	++	+++	++++	+++	++	+++	+++	+++
E. cloeziana									+++	++
E. dunnii							+++			++
E. grandis/saligna (10)	+++		+	+	++	+++	+++	+++	++	+++
E. pellita						+++	+			
E. urophylla (11)						+++	+++			+
E. nitens										
E. urograndis(12)						+++	+++		+	+
E. robusta						++				
E. rostrata				+++						

Species	Countries									
	Ang	Bot	Les	Mad	Mal	Moz	SA	Swa	Zam	Zim
Acacia mearnsii (14)			++	+	++	++	+++	+++		+++
A. mangium	+++			++						
Casuarina equi-setifolia (13)	++	++		++	++	+++	++	+	+	++
Cupressus (15)	+	+	+	+	+	+	+	+	+	+
Tectona grandis					+	++				
Gmelina arborea					++				++	+

+ cited in literature, ++ important +++ identified as a priority species/grown commercially

7.4. INDIGENOUS FRUIT TREES

All countries except Lesotho reported on prioritising the collection and improvement of at least one indigenous fruit tree. Table 25 shows the priority list of species that are cited in literature or mentioned by experts. Using vegetative material as a source of planting appears to be the most feasible way of deploying fruit tree germplasm. The provenance trials of some of the species in different countries are providing valuable information on performance and adaptability. Large quantities of fruits are still being collected from wild populations. The impact of fruits (germplasm) translocation could alter the genetic composition of natural populations, disrupting the continuous evolution of tree populations at a given site and reducing the regenerative capacity of some species. There is a need to evaluate the impact of commercialisation on natural populations and identify areas that can be set aside for *in situ* conservation.

Table 25. Country-species matrix for most commonly planted indigenous fruit species.

Species	Countries									
	Ang	Bot	Les	Mad	Mal	Moz	SA	Swa	Zam	Zim
Adansonia digitata		+++		+++	+++	++	+++	++	++	++
Parinari curatellifolia	++	++		+ exotic	+	+++	++	++	+	+++
Sclerocarya birrea		+++			+++	++	+++	+	+	+++
Strychnos cocculoides	+	++			++	+	+		+++	++
Uapaca kirkiana	++			+ exotic	+++	+++			+++	+++
Ziziphus mauritiana	+++	+++		+++	+++	+++	+++	+++	+++	+++

+ cited in literature, ++ important +++ identified as a priority species/grown commercially

7.5. MULTIPURPOSE AND AGROFORESTRY SPECIES

MPTS and agroforestry species have a fairly recent history in the region (see Table 26). ICRAF, in Malawi representing the region, has spearheaded the research. There is a lot of germplasm in the region that is being deployed to farmers. Most NTSC, except Malawi, reported that they did not collect or distribute agroforestry tree seeds. The perception reported by most seed centres is that putting in place a strategy to collect agroforestry seed is difficult and may be costly since the markets (end-users) keep changing. The fact that most of the demand for such species is driven by donor projects creates a level of uncertainty, and Forest Departments tend to favour long-term research funded from government fiscal allocations. In countries where there is a strong demand (Malawi), the seed business has attracted several stakeholders and there is no control or capacity to monitor the quality of the seeds. There is need to set standards and improve the capacity by government to monitor. Sustainability of planting agroforestry species beyond the tenure and involvement of international organisations need to be evaluated since the perception that the activities are donor driven is quite common and ingrained.

Table 26. List of agroforestry species common in the region.

Species	**Countries**									
	Ang	**Bot**	**Les**	**Mad**	**Mal**	**Moz**	**SA**	**Swa**	**Zam**	**Zim**
Calliandra calothyrsus	++									
Faidherbia albida	+	++			+++	+++	++	+	+++	+++
Gliricidium sepium	+				+++	++			+++	++
Leucaena leucephala	+	+		++	+++	++	+	+	+++	+++
Senna siamea					++	++			+++	++
Senna spectabilis					+++	+			++	+
Sesbania sesban	+	+		+	+++	++	+	+	+++	++
Tephrosia vogellii					+++				++	+

+ cited in literature, ++ important +++ identified as a priority species/grown commercially

All countries mentioned *Faidherbia albida* as the top choice for farmers and it is recommended that more attention need to be paid to the species for improvement and improved seed supply.

7.6. COMMERCIALLY IMPORTANT AND ENDANGERED SPECIES

Table 27 lists a number of commercially important species that are harvested for timber. These species have been mentioned in literature as priority for conservation. In Mozambique, harvesting contractors are required to plant seedlings of harvested species, but survival is rarely monitored. Forest departments need to come up with management plans that ensure compliance that harvested forests are restored. These plans may include collecting seed of all the species in the area to be harvested and replanting the areas using the retained seed. Natural regeneration from stumps can be encouraged and ecological restoration using short-lived canopy species (e.g. in Madagascar, see Manjaribe *et al*., 2013) can be tried in the degraded forests. Such approaches require detailed knowledge of the ecology of the forests. The artificial regeneration disrupts the continuous evolution of tree populations at a given site, but opens opportunities for increasing genetic diversity and enhancing productivity through the selection of superior provenances (White *et al*., 2005). Some species, like *Khaya nyasica* is fairly widely grown in plantations within its natural area of distribution, but also in South Africa, tropical Asia and tropical America, and there should be active promotion of the planting of such species using superior provenances.

Table 27. List of commercially important species that are harvested for timber

Species	**Countries**										
	Ang	**Bot**	**Les**	**Mad**	**Mal**	**Moz**	**Nam**	**SA**	**Swa**	**Zam**	**Zim**
Afzelia quanzensis	++	++			+++	+++		++	+	+++	+++
Baikeaea .plurijuga	++	++								+++	+++
Delbargia melanox-ylon	++	++			++	++	++	++	++	+++	+++
Khaya nyasica	++				++	+++		+ exotic		++	++
Milicia excelsa	++				++	++				+	++
Pterocarpus ango-lensis	++	++			++	+++	++	++	++	+++	+++

+ cited in literature, ++ important, +++ identified as a priority species/commercially exploited

There is increasing need for the Southern Africa region to review *in situ* conservation to ensure that the tree species and forest genetic resources are comprehensively and adequately represented (e.g. Australian and New Zealand Environment and Conservation Council, 2001). This would require governments in the region to come up with joint actions, since most of the species' geographical distribution spans across national boundaries (e.g. strict natural reserves such as those established in Zimbabwe can be extended across boundaries).

7.7. TREE SEED PRODUCTION SYSTEMS IN SOUTHERN AFRICA

NTSC in Southern African countries received considerable support from CIDA between 1992 and 2000. The support included vehicles and equipment, training, and a cadre of seed professionals was set up in the region. There were a lot of regional training workshops, scientist exchange visits and research seed-lots exchange. However, over the years there has been no significant investment in NTSC activities. Seed centres in Malawi and Zimbabwe are still functional to some extent, whereas those in Zambia and Mozambique are experiencing shortages in human capacity and funding. The seed centres are failing to meet domestic seed demands and private forest companies and tree growers are relying on seed imports. In South Africa, most private forest companies have their own seed orchards and have progressed to clonal forestry practice. Thus, the materials are bred for specific environment and use (e.g. fibre) and may not be suitable for other environments. A number of private growers in the region have imported eucalypt clones from South Africa and reports suggest more failures than successes and, possibly, the vegetative material is helping the spread of diseases and pests.

P. tecunumanii, *P. maximinoi* and *P. caribea* seed is difficult to acquire since most seed orchards are young and the species are generally shy seed producers. There could be an opportunity for collaborative research where seed orchards can be located in countries with suitable conditions for seed production and the national seed centres could be contracted to maintain orchards and supply seed. By using regional statistics on rates of afforestation and reforestation, seed centres will be able to better plan for the rejuvenation of seed orchards of traditional species (*P. taeda, P. elliottii* and *P. kesiya*). There are also opportunities to unlock value in the forest industry by leveraging the tree breeding and seed supply strengths of the various countries in the region. This would require information exchanges at the regional levels. There is one opportunity that exists through the Southern African Tree Seed Working Group (SATS) that was formed in 2002 by forestry stakeholders in South Africa to create a forum for discussion, debate and the exchange of scientific ideas around tree seeds and seed orchards (Luke Solomon, personal communication, 2014). AFF can work with SATS to raise awareness on the need to use good tree germplasm.

Collections of indigenous species tend to be on an *ad-hoc* basis for ornamental plantings and for small research projects. There is scope to use the opportunities during collection to gather information on species growth and collect herbaria specimens and contribute to the understanding of the ecology of many species. This work will feed into strategies to manage natural woodlands and forests to achieve SFM.

It was difficult to assess whether the seed centres were following International Seed Testing Association (ISTA) rules. For Zimbabwe, seed for export (pines and eucalypt) is tested by the government seed testing laboratory which is an ITSA accredited institution. The rest of the species are tested using locally developed protocols to suit the type of seed. It would appear that the need to follow ISTA rules is based on whether the seed is being exported and whether the importing country requires phytosanitary certification. Private companies in Mozambique expressed the problems they face when importing seed, and there are calls for some harmonisation of regulations at the regional level bearing in mind that regulations are usually set for seed for agricultural crops.

8. Conclusion

The study reviewed tree breeding and tree germplasm supply in the southern Africa region. It is quite clear that the region has a good assemblage of forest genetic resources for fast-growing exotic species (pines, eucalypts and acacias) for plantation development and has made significant progress in introducing some species for agroforestry. There is growing concern of the increasing backlog of tree planting, and this together with increasing temporarily unplanted areas and the finite land on which to plant trees would require research to ensure that good genetic material is available to increase productivity and profitability. The new afforestation frontier in Mozambique is requiring new species and offers an opportunity for collaboration between companies and countries, and creates some scope for regional exchange of research information.

The work on MPTS and agroforestry species has been led by international and local NGOs, and there is need for governments to get involved in scaling-up the activities through facilitating germplasm deployment. The lists of priority agroforestry species vary from project to project and from country to country, which makes it difficult to come up with a long-term tree breeding and seed production strategy. There are too many players in the agroforestry seed production system and there is need to develop some guidelines and improve monitoring of quality. For indigenous fruit trees, the development of vegetative propagation technologies has shown some promise and could make deployment easier. Collections for commercially important indigenous species is still very much *ad-hoc* and limited to research projects. However, the collection missions are helping provide information on species distribution that is so vital in the *in-situ* conservation of the species and ecological restoration after harvesting.

The disinvestments in research have also affected the seed centres. Most of the seed centres have reported reductions in skills and lack of equipment. This is creating bottlenecks in the seed production and supply with reports of loss of viability and poor germination of seeds. ISTA rules appear to be applied only to commercial pine and eucalypt seed destined for export and where phytosanitary certification is required.

The different custodians of tree genetic material in the region have a unique resource, and through policy and regional programmatic support, there are opportunities to share the information and materials to improve performance of planted trees and plantations and achieve SFM in the region.

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African Forest Forum
United Nations Avenue, Gigiri.
P.O. Box 30677-00100, Nairobi, Kenya
Tel: +254 20 722 4203
Fax: +254 20 722 4001
E-mail:exec.sec@afforum.org

Website: www.afforum.org.
Twitter @ africanff.
Facebook / African Forest Forum.
LinkedIn / African Forest Forum (AFF).