World Agroforestry Centre
TRANSFORMING LIVES AND LANDSCAPES

ICRAF AGROFORESTRY TREE GENETIC RESOURCES STRATEGY 2013-2017

The World Agroforestry Centre (ICRAF) is part of the alliance of the Consultative Group on International Agricultural Research (CGIAR) centres dedicated to generating and applying the best available knowledge to stimulate agricultural growth, raise farmers' incomes and protect the environment.

ICRAF's **vision** is a rural transformation in the developing world as smallholder households strategically increase their use of trees in agricultural landscapes to improve their food security, nutrition, income, health, shelter, energy resources and environmental sustainability.

ICRAF's **mission** is to generate science-based knowledge about the diverse roles that trees play in agricultural landscapes, and use its research to advance policies and practices that benefit the poor and the environment.

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List of abbreviations & acronyms

CBD	Convention on Biological Diversity
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Center for International Forestry Research
CRP	CGIAR Research Programme
FAO	Food and Agriculture Organization
FRA	Forest Resources Assessment
GIS	Geographic Information Systems
GRIN	Germplasm Resources Information Network
IA	Intellectual Assets
ICRAF	World Agroforestry Centre
IUCN	International Union for Conservation of Nature
MSB	Millennium Seed Bank
NARS	National Agricultural Research Systems
SMTA	Standard Material Transfer Agreement
UK	United Kingdom

Summary

Tree diversity in forests, on farms and in agricultural production landscapes – the corner stone of resilience and a key contributor to rural safety nets in those landscapes - is threatened by deforestation, degradation and destruction of natural habitats, including clearing for urban centres, settlement and farming, logging, forest fires, insect pests and diseases, natural disasters, climate change and invasive species. *Ex situ* conservation of threatened tree diversity, particularly for species with a current or potential use in agroforestry systems, is one solution to secure germplasm for current and future use.

The ICRAF Genetic Resources Unit has a global role to collect, conserve, document, characterize and distribute a diverse collection of agroforestry trees, mainly focusing on indigenous species. The ICRAF seed and field genebanks were established to ensure the supply of superior tree germplasm for research, to conserve material for the benefit of present and future generations, and to identify and make available superior planting material to smallholders to support their livelihoods and the sustainable use of tree diversity. The current aim of *ex situ* conservation activities at ICRAF is to have a world class agroforestry tree germplasm resource and develop a global conservation system for priority agroforestry trees. This implies conserving collections to international standards, encouraging quality research to fill information gaps and promote use, and sharing knowledge and germplasm to improve livelihoods. The strategy for ex situ conservation of trees has to take into account the large number of genera, long generation intervals, large growth forms, generally outbreeding reproductive systems and species-specific regeneration requirements. Decentralized and complementary conservation methods are required, including seed genebanks, live *ex situ* field genebanks, conservation *circa situ* (in farmland around natural forest where species are or were once found) and *in situ* (in the wild). This strategy is mainly concerned with the *ex situ* conservation of agroforestry trees and does not deal with *in situ* conservation.

A five-year action plan to be implemented in partnership with collaborating NARS and farmers is presented to attain the standards required of a world class agroforestry tree germplasm resource with the following elements:

i. Germplasm collection, acquisition and rationalization
The ICRAF collection of priority agroforestry tree species will be expanded to fill important gaps in the coverage of the genepool and rationalized as needed after review of diversity based on the results of characterization and eco-geographic mapping

ii. Assuring quality materials for use
Management protocols will be developed on a species-specific basis, based on the breeding system, population genetics and diversity, for priority species to minimize/eliminate loss of genetic integrity during regeneration.

iii. Conservation of priority agroforestry tree species
Management of agroforestry tree accessions will be in line with the draft genebank standards for seed and field genebanks.

iv. Information management and knowledge sharing
ICRAF will maintain, improve and expand datasets for management of accessions to increase the utility of the collection and respond to users' needs for additional information.

v. Studying diversity of priority agroforestry tree species
Characterization will use species-specific characterization/evaluation morphological descriptors to describe the diversity within the collection.

A. Introduction

Although the global rate of deforestation has decreased over the past ten years from an estimate of 16 million hectares per year for 1990–2000 period to 13 million hectares between 2000-2010, deforestation continues at an alarmingly high rate in many countries[1]. It is estimated that at the end of the last millennium, around 10% of the world's 60,000 to 100,000 tree species were threatened with extinction[2]. Loss of forests and woodlands is a practical concern for rural communities in the tropics that have traditionally depended on them for various resources. Interestingly, the largest proportion of the loss in primary forests are mainly in ICRAF working regions led by South America, followed by Africa and Asia. Current IUCN Red List of Threatened Species (www.iucnredlist.org), indicates approximately 1,200 trees and shrubs as "critically endangered", 1,700 as "endangered" and another 3,700 as "vulnerable". The major threats to forest biodiversity include clearing for urban centres, settlement and farming, logging, forest fires, insect pests and diseases, natural disasters storms and earthquakes, climate change and invasive species. Most of these threats are still a concern even for *in situ* conserved material.

Trees differ from crops so the standard model used for the management and *ex situ* conservation of genetic resources of food crops only partially apply. The large number of genera, long generation intervals, large growth forms, generally outbreeding reproductive systems and species-specific regeneration requirements of agroforestry trees require a complex and more flexible system for the management and conservation of genetic resources. Decentralized and complementary conservation methods are required, including seed genebanks, live *ex situ* field genebanks, conservation *circa situ* (in farmland around natural forest where species are or were once found) and *in situ* (in the wild).

Although seed storage is an attractive conservation method for orthodox-seeded trees, a significant limitation is the need to regenerate stored samples periodically. This is expensive and difficult, especially if a representative range of populations is to be maintained rather than just one or a few stands of each species. Undertaking regeneration with growers that obtain some benefits from planting is a way of reducing land and maintenance charges that are the major costs in the process. For economically important trees with recalcitrant seed and/or that are propagated clonally to maintain genetic integrity, costly maintenance may make field genebanks financially unviable.

In order to improve the efficiency of management of woody species, live stands are often used for multiple purposes. A stand may function as a field genebank, evaluation block and source of seed or vegetative material for further planting, provided that genetic diversity, genetic integrity and survival are assured through minimum numbers of individuals and appropriate management practices. Combining conservation with domestication efforts and linking conservation to the supply of seed for sustainable use are appropriate ways to maximize the benefits from *ex situ* genebanks of agroforestry trees.

This current strategy is concerned with the *ex situ* conservation of agroforestry trees and does not deal with *in situ* conservation. Farm diversification and reduced forest pressure supporting *in situ* conservation are important outcomes from other activities within the World Agroforestry Centre (ICRAF). Optimum approaches and choices to combine conservation with use are needed to ensure

[1] FRA (2010) Global Forest Resources Assessment 2010 CD-ROM FAO Rome.

[2] Ian K Dawson, Manuel R Guariguata, Judy Loo, John C Weber, Ard Lengkeek, David Bush, Jonathan Cornelius, Luigi Guarino, Roeland Kindt, Calleb Orwa, Joanne Russell, and Ramni Jamnadass. What is the relevance of smallholders' agroforestry systems for conserving tropical tree species and genetic diversity in *circa situm*, *in situ* and *ex situ* settings? A review. Biodiversity and Conservation (in press)

the sustainable use of agroforestry tree germplasm through supporting domestication efforts to improve smallholder livelihoods. These wider issues of conservation and use in different settings are addressed at length in a recent paper commissioned as a collaborative activity under the auspices of CRP6 and led by ICRAF staff with support from Bioversity International and CIFOR [2].

B. Background

The specific objectives of establishing ICRAF genebank activities are to ensure the supply of superior tree germplasm for research, to conserve material for the benefit of present and future generations, and to identify and make superior planting material available to smallholders to support their livelihoods and the sustainable use of tree diversity. The ICRAF Genetic Resources Unit has a global role to collect, conserve, document, characterize and distribute a diverse collection of agroforestry trees, mainly focusing on indigenous species. Research also includes methods to maintain between and within species diversity of agroforestry trees.

The agroforestry tree genetic resources collections in ICRAF can be divided into two types of materials: those conserved as living trees in field genebanks and those conserved as seed stored in seed genebanks. Only orthodox seed can be stored for any period of time in the latter manner, although many trees that produce orthodox seed are also maintained as field collections because they are distributed vegetatively as true to type materials or because of long generation intervals and high demand for seed. Most fruit trees are maintained as field collections because their seed are often recalcitrant, semi-recalcitrant or intermediate and desiccation sensitive, and/or because true-to-type clone maintenance is important. The material type – both its use and biology – therefore has significant effects on the options for, and costs of, conservation.

Medium term seed storage facilities were established in Nairobi, Kenya in 1997 for *ex situ* conservation of seeds. Long-term storage is currently done under agreements with the Millennium Seed Bank (MSB) in the UK and Kunming in China. These agreements do not include monitoring/regeneration and seeds will need to be returned to ICRAF for viability monitoring and later regeneration. Field genebanks were established for *ex situ* conservation of vegetatively propagated species and also for trees propagated by short-lived seeds or with high demand for planting material. These serve as conservation blocks and provide a source of clonal material or seeds for distribution.

ICRAF works with NARS in East Africa, Latin America, Southern Africa, South East Asia, South Asia, and West and Central Africa to establish and manage field genebanks. Most are based on collections established under specific projects where conservation was opportunistic and not a primary objective. Since ICRAF does not own land, field genebanks are managed in collaboration with national partners and/or farmers. Although this increases the vulnerability of the collections due to changing interests and hence uses for land on the part of these partners, it remains one of the most efficient and cost effective methods for long-term conservation of these species.

ICRAF's current genebank activities include:

Germplasm acquisition and distribution –a working germplasm collection is maintained at HQ genebank and field genebanks for research and pilot developmental programmes with partners. In addition ICRAF holds a collection of agroforestry tree germplasm for conservation that has been assembled over many years (Tables 1, 2 and 3).

Seed processing – Orthodox seeds are dried at 15^0C and 10-15% relative humidity to moisture levels of 6-10% before storage.

Viability testing – Seeds with an initial viability of between 40% and 90%, depending on the type of species, are accepted for storage. Periodic viability assessments are done every five to ten years during storage, depending on the species.

Seed genebanks – 3,705 accessions representing 209 different tree species are stored in laminated aluminium bags or larger airtight containers at temperatures of 0-5^{o}C in medium term storage at ICRAF in Nairobi (Table 1). Longer term storage is done with national partners in base collections in the Kunming genebank, China and the MSB, UK at lower temperatures of -18^{o}C to -20^{o}C (Table 2).

Field genebanks – Over 10,000 accessions established either from seeds or clonally located in the different regions where ICRAF works (Table 3). They are used for clonal multiplication, distribution and evaluation, as well as for conservation.

Safety duplication – Over 500 accessions representing 120 agroforestry tree species are duplicated in black box storage in the Svalbard Global Seed Vault, Norway (Table 2).

Regeneration – Regeneration is used to renew accessions when seed viability is low (seed genebanks) or trees lose vigour or die (field genebanks).

Molecular characterization of genetic variation – An initial characterization of variation is important for determining the diversity of material for establishment or rationalization of collections in field genebanks in particular. Molecular fingerprinting is used to identify duplicates and facilitate comparison of farmer cultivars.

Knowledge sharing – the Genetic Resources Unit has developed and manages two major online open access databases to encourage the use of quality, site-matched agroforestry tree germplasm. The first, the Agroforestry Database, contains information on the management and use of more than 650 tree species important to smallholders in the tropics. The second, the Tree Seed Suppliers Directory, provides information on more than 100 global suppliers of tree seed for over 5,000 tree species

Table I: Tree species and number of accessions stored at ICRAF seed genebank in Nairobi

Species	Accessions	No. of countries represented
Acacia erioloba	135	4
Acacia karroo	435	4
Acacia tortilis spirocarpa	132	5
Calliandra calothyrsus	371	9
Faidherbia albida	845	9
Gliricidia sepium	218	7
Leucaena diversifolia	75	4
Leucaena lempirana	70	1
Leucaena salvadorensis	83	2
Leucaena shannonii	69	3
Other less represented species	1273	> 10
Total	**3706**	

Table 2: Tree species and number of accessions stored in partner seed banks

Species	Kunming	MSB	Svalbard
Acacia tortilis heteracantha	41		41
Acacia tortilis spirocarpa	19		19
Albizia nipoides	24		24
Calycophyllum spruceanum		330	
Faidherbia albida	108		108
Gliricidia sepium	56		56
Guazuma crinata		346	
Leucaena collinsii collinsii	13		12
Leucaena diversifolia	16		16
Leucaena magnifica	24		24
Leucaena shannonni	16		16
Prosopis africana		834	
Other less represented species	453		461
Total	**770**	**1510**	**777**

Table 3. Collections held at ICRAF field genebanks

Region	Agro-ecological zone	No of countries represented	No of locations	No of species	Managed by
Latin America	Humid-tropics	1	1	3	ICRAF and national partners
East Africa	Sub-montane	4	14	11	ICRAF projects, farmers and national partners
West and Central Africa	Humid-tropics and moist deciduous	8	7	31	ICRAF projects and national partners
South East Asia	Humid and Sub-tropic highlands	3	5	70	ICRAF projects and national partners
South Asia		2	7	6	ICRAF projects and national partners
Southern Africa	Semi-arid, sub-tropical highlands and sub-humid sub-tropical	4	28	18	ICRAF projects, communities and government funds
	Total	**22**	**62**	**139**	

Genetic considerations for conservation of agroforestry trees

Collections are composed of genotypes which represent the genetic diversity within the species. In genetic resources and genebanks the individual units of germplasm that make up the collections are known as accessions, defined as:

- Plant sample, variety or population held in a genebank or breeding programme for conservation or use.

- A collection of plant material from the same species from a particular location.

Accession refers to uniqueness in genetics, location and time. This means that it is important to document exactly what the material is and how it was collected to be considered as an accession. Terms that provide unique identification of an accession that are commonly used for agroforestry include seed lot, stand, population, landrace, family, clone, variety, plus tree, provenance, genotype, mother tree and plant sample.

Most tree species are preferentially out-crossing and can suffer from inbreeding depression if genetic variation is low. High levels of genetic variation in populations may also be an important feature for providing an adaptive capacity to changes in pest and disease prevalence, the varying requirements of users, and an altering global climate. The impact of climate change on agroforestry practices requires range-wide sampling exercises, to collect germplasm and conduct research to identify planting material that is suitably adapted to new environmental conditions. Germplasm collection from drier locations may be particularly useful for possible future use, as well as for conservation purposes. These natural populations may be at particular threat as climate gets drier. One example is provided by prosopis (*Prosopis africana*), used by local people primarily for wood production, in the Sahel.

Range-wide collection, which involves surveying the natural distribution of a species and sampling provenances from discontinuous stands in different ecological conditions, such as rainfall level, soil type and temperature range, is a useful strategy for germplasm collections. Many planted populations of a widely cultivated species may be of limited or common origin from the same original provenance which has been distributed from site to site across the world. Thus, care must be taken when sampling non-indigenous species because the same source may be found in a broad range of locations; its multiple sampling may give a false impression of the diversity thereby conserved. Range-wide collections provide for the full evaluation of genetic variation within a species and for conservation.

Molecular markers provide a complementary method to field observations and nursery trials to evaluate genetic diversity. They provide information about the biological processes involved in shaping genetic structure and can also be used to compare natural, managed and cultivated tree stands to determine the impacts of logging, deforestation and past domestication. Although they provide good opportunities, molecular marker methods also have limitations. Most importantly, they are not generally directly linked to the adaptive capacity or productivity of individual trees and are therefore no substitute for field evaluation. New powerful molecular tools that reveal many polymorphisms located across the genome and that can be linked to key adaptive traits are beginning to be developed for trees, and these will in the future help bridge the gap between genetic variation in the genome and form and function.

C. Vision and aim: developing a global conservation system for priority agroforestry trees

Considering the large number of tree species important to smallholders across agro-ecoregions and the high genetic diversity often found within them, the potential scope for conservation and sustainable use activities is very large. The current aim of *ex situ* conservation activities at ICRAF is to have a world class agroforestry tree germplasm resource and develop a global conservation system for priority agroforestry trees. This implies conserving collections to international standards, encouraging quality research to fill information gaps and promote use, and sharing knowledge and germplasm to improve livelihoods.

1. Priority setting

Although species priority setting has been an important activity for deciding which trees to promote and domesticate within ICRAF regional programmes[3], no specific priority setting exercise has been carried out to determine targets for conservation. Priority setting for conservation overlaps but in important elements is different from that for domestication. As well as market considerations, it takes into account the level of diversity and degree of threat to the resource and existing conservation initiatives, as well as the potential for current and future use of the tree. A clear process of priority setting for conservation will be carried out by region over the next five years to determine which species to focus on. Priority setting is an ongoing dynamic process to meet current and future needs, and requires a broad perspective to respond to global challenges such as climate change. Ongoing consultations with partners and farmers will be needed to ensure that the collections remain relevant to their needs. Criteria used to determine key species for conservation during this process will include:

- Global importance
- Market demand and importance to livelihoods (health, nutrition, income) of farmers
- Domestication suitability for cultivation, production and processing
- Level of coverage by other conservation efforts, including the long-term viability of *in situ* methods, and genebanks
- Availability of potential partners for conservation
- Gaps in collections
- Level of threat, endangered nature of the species and its role in the environment for supporting the sustainable use of other flora and fauna
- Presence of useful adaptive traits such as drought tolerance, salt tolerance and resistance to pests and diseases.

The amount of genetic diversity within the key agroforestry species and access to this diversity within the access and benefit sharing conditions of international treaties, distribution and knowledge about the species and funding will determine the size of species-specific collections. Representative samples will be collected across the distribution range to capture a wide range of diversity.

[3] Franzel, S.;Kindt, R. 2012 Species priority setting procedures : In: Dawson, I., Harwood, C., Jamnadass, R., Beniest, J. eds. Agroforestry tree domestication: a primer. Nairobi: World Agroforestry Centre ICRAF , Kenya p. 36-45

2. Information gaps for agroforestry tree species

Information management is an ongoing activity as new data is gathered from collection and characterization and information gaps on passport data and inventories are filled. Further characterization and evaluation of diversity within collections is important to generate information to facilitate targeted selection of germplasm and species by users.

Geographic information systems (GIS), including geo-referencing software, can be used to facilitate diversity assessments within species and to carry out gap analysis. This involves mapping geographical distributions and estimating how much of the distribution has been sampled, to target future collections as well as to recollect from specific locations. GIS can also be applied to identify suitable locations for field genebank establishment and to delimit appropriate cultivation zones to facilitate use, including in the context of a future changing climate.

Lack of information on the reproductive and population biology of many agroforestry trees, together with little information on the amount of genetic diversity in the genepool, have resulted in a complex and subjective decision-making process of what to collect and conserve and how to ensure the genetic integrity of the materials already in collections. There is also a lack of knowledge on appropriate seed viability testing methods, on optimum management approaches to maintain field genebanks, on the susceptibility of seed and live trees to diseases and pests, and on the biosecurity risks associated with germplasm exchange (risks of the trees as invasive and risks to other plants from any transmitted pathogens). Optimum monitoring and regeneration intervals are not yet developed for the seed of many agroforestry species due to lack of data on longevity under storage. This can result in unnecessary and costly monitoring. Research on approaches that maintain viability in storage and therefore increase the time before seed need be regenerated, such as seed cryopreservation, is therefore critically important. This information gap needs to be filled to improve the management of the *ex situ* collections.

3. Access to materials from the genebank collections

In line with the Consultative Group on International Agricultural Research (CGIAR) Intellectual Assets (IA) principles[4], ICRAF considers its germplasm collections as global public goods and is committed to the widespread diffusion and use of material and information to achieve the maximum possible access, scale, scope of impact and sharing of benefits to advantage the poor, especially farmers in developing countries. All intellectual assets produced or acquired by the CGIAR Consortium and/or the Centres are managed in ways that maximize their global accessibility and/or ensure that they lead to the broadest possible impact on target beneficiaries in furtherance of the CGIAR vision.

Management and growth of the ICRAF agroforestry tree germplasm collection will be conducted in accordance with all applicable laws and the CGIAR IA principles and ICRAF policy on genetic resources[5]. ICRAF is committed to the principle of unrestricted availability of genetic resources in

[4] CGIAR IA principles relating to Genetic Resources for Food and Agriculture under the Common Operational Framework as of 7 March 2012:

4.1 The CGIAR supports the effective conservation and widespread use of all genetic resources for food and agriculture.

4.2 Facilitated access to Plant Genetic Resources for Food and Agriculture within the purview of the Treaty shall be provided in accordance with the Treaty and these CGIAR IA Principles. In addition, the acquisition or transfer of any other genetic resources by the Centres shall be conducted in accordance with all applicable laws including those implementing the CBD, as well as these CGIAR IA Principles.

[5] ICRAF Policy Guideline series: Tree genetic resources policy for ICRAF, revised January 2011.

accordance with national legislation and the agreement with the Governing Body of the International Treaty on Plant Genetic Resources for Food and Agriculture (Treaty) of 2006 placing in trust materials under the auspices of the Treaty. ICRAF will review the legal status of collections managed in field genebanks under its programmes with national partners to assess the legality of placing additional relevant collections of agroforestry trees under the Treaty. Protocols will be updated for sharing of material with partners and the standard material transfer agreement (SMTA) is being used for transfer of germplasm to recipients.

Germplasm delivery systems for agroforestry trees generally do not follow a formal breeding and delivery approach. Lack of access to high quality planting material of a wide range of tree species to small-scale farmers constrains their adoption of agroforestry practices. Improving the ways by which growers gain access to planting material is therefore crucial in bringing trees into cultivation on farms, and thus is an essential consideration in tree domestication strategies. Considering the variation in species of interest between different countries and even different regions of the same country, local field genebanks and seed orchards will be used in addition to the conventional seed genebank to meet needs. In order to make the germplasm available to a diverse set of users, germplasm will be made available on a non-profit basis to cover the costs of production.

4. Partnerships

Partnerships involving the sharing of responsibilities for conservation and management are central to this strategy. ICRAF will continue to work closely with existing national and international partners in the regions and will seek and initiate new partnerships for conservation as needed, based on the ICRAF partnerships strategy and guidelines[6]. The modalities for involvement of different partners will vary depending on local conditions and needs. However, all partnerships will be governed by contracts that identify responsibilities and cost sharing arrangements. Service agreements will be concluded with service providers or partners taking on specific responsibility for conservation or testing.

Capacity building is a requirement of all scientific staff within ICRAF[7]. Staff capacity in conservation and sustainable use of agroforestry trees and access and benefit sharing mechanisms will be improved. ICRAF intends to develop educational materials to address policy issues and raise awareness of policies, agreements and conventions to support effective compliance.

A global system will require substantial funding to support joint activities. ICRAF will develop funding proposals with partners to seek joint funding to support a collaborative research agenda in line with ICRAF fundraising guidelines.

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[6] ICRAF Partnerships Strategy and Guidelines, 2008.
http://www.worldagroforestrycentre.org/downloads/publications/PDFs/MN15943.PDF

[7] ICRAF Policy Guideline Series 4: Human Resources Policy and Procedures Manual, 2011.

D. Five-year action plan

1. Germplasm collection, acquisition and rationalization

The ICRAF collection of priority agroforestry tree species will be expanded to fill important gaps in the coverage of the genepool and rationalized as needed after reviews of diversity based on the results of characterization and eco-geographic mapping. Collections will be expanded through both acquisition and collection in close collaboration with national partners within the principles of the Convention on Biological Diversity (CBD).

New strategies to determine the distribution range of species for structuring collection missions based on vegetation maps, geo-referenced environmental data sets such as those in WorldClim, diversity within species, taxonomy and uniqueness of populations, will be developed to guide additional collection for diverse germplasm of agroforestry trees. A number of different provenances or populations will be collected for comparison because considerable genetic variation in important adaptive and productive traits can exist within tree species. Provenances and sites for collection will be selected based on criteria such as:

- Coverage of the full latitudinal range of the species
- High rainfall and lower rainfall sites, where appropriate
- High, intermediate and low altitude sites
- Riverine and forest habitats.

The focus during collection will be on sampling wild sources. However, if there is any cultivation history of species of planted populations, a few will also be collected for comparison during subsequent evaluations.

2. Assuring quality materials for use

Management protocols will be developed on a species-specific basis based on breeding system, population genetics and diversity for priority species to reduce loss of genetic integrity during regeneration. An initial characterization of variation, using both traditional descriptive morphological characterization and molecular tools to identify individuals with maximum diversity and avoid unintentional duplication of accessions within the collection will continue to be employed to minimize the high maintenance costs of conservation of agroforestry tree species whose seed cannot be kept viable for any length of time under conventional dry cool storage.

Proactive research based on the genetic material in the collection will be promoted. New research will be initiated on *Faidherbia albida*, which is at the centre of a current movement on Evergreen Agriculture and for which ICRAF holds one of the most important collections worldwide. Internship and training programmes will be established in the medium term to strengthen capacity for agroforestry science and practice, and will be funded through new research proposals to carry out specific research to fill the most pressing information gaps, such as the impact of climate change on species distribution and diversity. ICRAF will work with national partners and universities to establish collaboration and influence them to research the priority agroforestry tree species to generate seed biology information needed for efficient storage and management.

Research on seed storage and longevity of key species will provide the information to extend the storage period and reduce the need for frequent regeneration. Until such time as more species-specific scientific information is available, monitoring intervals of ten years will be used for seeds of leguminous species, as determined during routine testing in ICRAF and at the International Livestock Research Institute (ILRI). Seeds of other species will be monitored more frequently in the short term

to closely monitor for any signs of deterioration in storage. Monitoring intervals will be extended based on these results to the extent possible without compromising loss of accessions.

ICRAF will continue to work with national service providers to carry out viability testing and germplasm health testing where quality can be ensured and services provided at reasonable cost. An analysis of what activities to outsource and what to maintain in-house will be undertaken based on availability, quality and cost of services in different regions. Partnerships will be developed in regions with exchange of plant pathologists and entomologists to provide expertise and oversee service quality. Capacity building will be needed and outsourced to local universities.

Management of field genebanks, seed multiplication and regeneration will continue on a cost sharing basis in collaboration with national partners in the most suitable agro-ecology for the species based on contracts with clear assignment of responsibilities and benefits. This can include seed orchards, progeny trials, provenance plantations, mother blocks and natural stands that are managed and established in ICRAF regions in collaboration with national partners. Surplus materials from live genebanks will also be available for distribution.

3. **Conservation of priority agroforestry tree species**

Management of agroforestry tree accessions will be in line with the draft genebank standards for seed and field genebanks[8]. Decisions on seed storage management of specific species or accessions will be made on a case by case basis depending on seed storage traits, longevity, time to flowering/seed production and demand for planting materials, based on existing information or on information on related species, where available. Efficiencies in space usage will be made in the medium-term storage facility and expansion of these facilities may eventually be required as the collection grows over time. ICRAF will continue to store the seed collections in multiple locations as required. The additional need for long-term storage facilities in ICRAF HQ, either in a cold room or in individual deep freezers, will be considered as the collection grows, taking into account cost and efficiency of operations/access.

Conservation of trees that cannot be preserved as seed will be implemented in a decentralized network of field genebanks at locations where they are well adapted, and with appropriate management and control of pests and diseases. Improved models for conservation will be developed to take account of the multiple uses of the materials in the field genebanks and monitoring and management will be improved to meet international standards to ensure healthy trees for conservation and dissemination. Research on approaches on how best to combine conservation with use in field genebanks will be initiated. Partners will be sensitized on adherence to international regulations and treaties, including quarantine, access and benefit sharing, intellectual property and use of material transfer agreements. Seed germination testing and propagation methods suitable for farmer use will be developed for tree species managed in field genebanks to facilitate dissemination of planting material.

All materials in the seed genebank will be safety duplicated. MSB and Kunming will in future provide black box safety duplication for each other and ICRAF will send a second safety duplicate to the Svalbard Global Seed Vault as fresh seeds become available from regeneration. A system for long-term storage and safety duplication of accessions in field genebanks will also be developed with the possibility of using DNA or pollen banking for safety duplication of those species with recalcitrant seeds or that take many years to flower and produce seeds.

[8] Draft Genebank Standards for Plant Genetic Resources for Food and Agriculture developed by FAO for approval by the Commission on Genetic Resources for Food and Agriculture, 2012

4. Information management and knowledge sharing

ICRAF has adopted the GRIN Global database for management of agroforestry germplasm data. The organization will continue data verification and gap filling to include all data into this system. ICRAF will maintain, improve and expand datasets for management of accessions. Standard multi-crop passport descriptors and geo-referencing software will be used to augment location data to increase the utility of the collection and respond to users' needs for additional information. Suitability mapping for species distribution and suitability modelling for present and future climate scenarios will be explored. Ethnobotanic data will be collected and incorporated into the information system. Digital images will be used to describe the diversity in the collection. Field genebank maps will be developed and presented with accompanying documentation of each accession.

Research results will be published in peer reviewed journals to make information on agroforestry species more visible. The information generated will be used to develop knowledge products using Web 2.0 tools to share this information globally. The Agroforestree Database and Tree Seed Suppliers Directory will be updated to encourage the use of quality germplasm. Training tools and manuals on conservation and sustainable use of priority agroforestry tree species will be prepared for capacity building of a wide range of users. ICRAF will contribute to the Crop Genebank Knowledge Base and will upload information on the priority species into this tool.

5. Studying diversity of priority agroforestry tree species

Characterization will use species-specific characterization/evaluation morphological descriptors to describe the diversity within the collection. Genetic variation will be estimated in tree species using phenotypic measurements made in natural stands and field trials, and by asking the people who use trees about the characteristics they observe and value. Activities will focus on species for which ICRAF holds large or diverse collections, on which there is little existing data, and for which research could address important questions.

Molecular characterization will be used to understand the genetic variation within and between accessions and select genotypes for conservation to maximize diversity within few individual trees for conservation in field genebanks. It will also be used to identify duplicates in field genebanks and confirm identity during regeneration to improve the efficiency of genebank management. Molecular markers to assess how genetic variation is geographically structured among tree stands will be used to devise better strategies for sampling populations, so that collections are representative of the available diversity in a species.