A Global Strategy for the Conservation and Utilisation of Tropical and Sub-Tropical Forage Genetic Resources

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Abbreviations and acronyms

Abbreviation	Description
CBD	Convention on Biological Diversity (https://www.cbd.int/convention/)
CENARGEN	Embrapa Recursos Genéticos e Biotecnologia (https://www.embrapa.br/recursos-geneticos-e-biotecnologia)
CGIAR	Consultative Group on International Agricultural Research (http://www.cgiar.org/)
CIAT	International Center for Tropical Agriculture (http://ciat.cgiar.org/)
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária (https://www.embrapa.br/)
FEAST	Feed Assessment Tool (http://www.ilri.org/feast)
GCDT	Global Crop Diversity Trust (https://www.croptrust.org/)
GRC	Genetic Resources Centre
GRIN	Germplasm Resources Information Network (http://www.ars-grin.gov/)
IAT	Integrated Analysis Tool
ICRAF	World Agroforestry Centre (http://www.worldagroforestry.org/)
IGC	International Grassland Congress (http://www.internationalgrasslands.org/)
ILRI	International Livestock Research Institute (https://www.ilri.org/)
INIFAP	Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (www.inifap.gob.mx)
ITPGRFA	International Treaty on Plant Genetic Resources in Food and Agriculture (http://www.planttreaty.org/content/article-xiv)
KALRO	Kenya Agricultural and Livestock Research Organization (http://www.kalro.org/)
LAC	Latin America and the Caribbean
NARS	National Agricultural Research Systems
PGR	Plant genetic resources
R4D	Research for development
RNB	Root nodule bacteria
SADC	Southern African Development Community (http://www.sadc.int/)
SE Asia	Southeast Asia
SoFT	An interactive selection tool for tropical forages (http://www.tropicalforages.info/)
SPGRC	SADC Plant Genetic Resources Centre (http://www.spgrc.org.zm)
SSA	Sub-Saharan Africa
TSTF	Tropical and subtropical forages
USDA	U.S. Department of Agriculture (www.usda.gov/)

Executive Summary

Tropical and sub-tropical forages (TSTF) are critically important for their supply of feed and for environmental reasons in extensive and intensive livestock production systems in the developed and developing countries. There has been focussed collection and conservation of TSTF, and research on their diversity, adaptation and use for the past 60 years with the peak of activity being in the period between about 1970 and 1995. The decline in support for TSTF research since 1990 has not occurred everywhere. Nevertheless the global reduction in capability has been very significant and it has, strangely, coincided with the rapid growth in demand for livestock products internationally, and has resulted in reduced capacity and knowledge in the networks of national and international genebanks that maintain the world's TSTF collections. This decline in capacity and knowledge needs to be urgently reversed if the tropical and subtropical world is to have access to the best genetic material and forage knowledge to meet the growing demands for food and environmental outcomes.
The strategy described here has been developed with input from across the tropical forage genetic resources community and aims to build a strong, functional network of national, regional and international genetic resource centres, introducing efficiencies that will enable the most important germplasm to be conserved and studied, and enabling genebanks to adopt the role of knowledge managers and advisors for research and development programs. The strategy presents a number of next steps and longer-term objectives. The three main objectives are:

1. Rebuilding the community of TSTF genebanks and genebank users to develop closer collaboration and trust;
2. Take steps to ensure more efficient and rationalized conservation within and between genebanks;
3. Actively support utilisation by anticipating germplasm needs and responding more directly to users' requests for information and seeds.

To facilitate the implementation of the strategy with the TSTF community, it is proposed to engage an experienced consultant who will oversee this rebuild and will undertake a set of concrete actions that will also create greater cooperation between key national genebanks and the CGIAR centres as well as among CGIAR centres themselves.

Towards a Strategy

Introduction and background: The term tropical and subtropical forages (TSTF) as used here comprises a large number of mainly legume and grass genera and species that have contributed to the development of feed systems for large and small scale animal production, or have been collected with this potential in mind.

Key centres of diversity for TSTF are Central and South America and the Caribbean (LAC) in the case of legumes, and sub-Saharan Africa (SSA) in the case of grasses although there are several exceptions to this rule. For example some of the most important legume genera such as *Stylosanthes, Leucaena, Desmodium, Centrosema,* and *Gliricidia* are primarily American while important grass genera such as *Urochloa* (syn. *Brachiaria), Pennisetum, Megathyrsus* (syn. *Panicum*) and *Digitaria* have predominantly sub-Saharan African origins. The exceptions include the grass genera *Paspalum* and *Tripsacum* which are American, and the legume genus *Vigna*, which is mostly African in origin, and a number of significant legume genera and species of Asian origins (the genus *Pueraria* and several species of *Desmodium* or genera closely associated with *Desmodium*). A number of grass genera have both African and Asian distributions (e.g. *Cenchrus* and *Bothriochloa*).

Importance of forages: Tropical and subtropical forage genetic diversity have contributed to improved livestock production in a wide range of environments and farming systems with greatest impact being over the past 50 years. TSTF have underpinned large scale pasture-based beef production systems in subtropical and warm-temperate North America, South America, especially in Brazil, and in northern Australia, provided the essential feed-base for more intensive livestock production systems including intensive beef and small ruminant production and dairying in enterprises ranging from small scale to the largest commercial units. They are also important in feeding pigs in some regions. There are numerous documented cases of the impacts that forages have made in sown pastures, in agroforestry, cut and carry production systems, and alley cropping to name some (Shelton *et al* 2005; Batello *et al* 2008; White *et al* 2013). They are becoming even more important because the consumption of livestock products has increased rapidly across the tropics in past decades with parallel increases in feed and forages needed to support the ever-increasing range of evolving production systems.

Tropical forages have also delivered environmental benefits through their impacts on reducing soil erosion, through carbon sequestration (Thornton and Herrero 2010; Chan and McCoy 2010), reduced use of nitrogen fertilisers in green manure systems and by providing higher feed quality for ruminants with resultant reduction in greenhouse gas (GHG) emissions (Thornton and Herrero 2010). Other species of TSTF such as Napier grass (*Pennisetum* purpureum) and switchgrass (*Panicum virgatum*) have potential for use as feedstocks for cellulosic biofuels (Ziolkowska 2014).

Some “forage” species (mainly grasses) have become important in recreation use. Grass species such as Bermuda *(Cynodon dactylon),* Kikuyu *(Pennisetum clandestinum),* St Augustine (*Stenotaphrum secundatum*) and zoysia (*Zoysia* spp.) are amongst those that are widely used as turf grasses in various parts of the world, with some of these species being the basis of high-value industries.

Some tropical forages, however, have also become serious environmental weeds due to their invasiveness. Much of the weed concern is best documented for Australia (Lonsdale 1994) although there are weed concerns associated with TSTF in other countries. Kudzu (*Pueraria* spp.) was introduced into the USA as a potential forage legume but it is now recognised as major weed in southern USA. Even some of the most economically important forage species such as *Leucaena leucocephala* and *Pennisetum ciliare* (syn. *Cenchrus ciliaris*) are amongst those listed as serious environmental weeds in Australia.

Selection and breeding programs: Breeding programs have not been the “preferred” pathway to development of forage cultivars (Tsuruta *et al* 2015). Nevertheless they have been used over the past 50 years with some outstanding successes such as the introduction of resistance to major pests and diseases (e.g. spittle bug in *Urochloa* and anthracnose in *Stylosanthes scabra*). Some of the major breeding programs conducted in Australia between 1960 and 1990 included those on *Macroptilium atropurpureum* and *Leucaena leucocephala, Stylosanthes humilis*, *Stylosanthes scabra*, *Sorghum bicolor X halepense*, *Setaria sphacelata*, *Digitaria eriantha* and *Centrosema pascuorum* (e.g. Loch 2007). No major breeding programs have been conducted in Australia since about 1990. The USA has a number of active breeding programs. Those at a range of USDA locations include programs on forage sorghum *(Sorghum bicolor*), bermudagrass (*Cynodon dactylon*), and switchgrass, while the University of Florida has breeding programs for bahiagrass (*Paspalum notatum*), bermudagrass, perennial groundnut (*Arachis* spp.) and limpograss (*Hemarthria altissima*) (Blount 2015). The international centres have continued investment in major breeding programs. The program on *Urochloa* (syn. *Brachiaria*) spp. by CIAT has been one of the largest and most sustained with a number of new cultivars (cvv. Mulato and Mulato II being the most widely adopted) being released in the past decade. Brazil also has breeding programs on *Urochloa*, *Pennisetum* and

Megathyrsus maximus (syn. *Panicum maximum*). ILRI is working with EMBRAPA Dairy to exchange materials from the Brazilian breeding program in Napier grass and has recently invested in a molecular biosciences program which aims to exploit variation held in its genebanks to inform future breeding initiatives in forage species, including Napier grass.

There are probably < 10 major breeding programs currently operating in tropical and subtropical forages programs worldwide. Far more frequently, cultivars have been developed by comparison among wild populations, and/or selections from within wild populations. Some of the most important tropical and subtropical forage cultivars have been commercialised through straight selection from wild populations (*Stylosanthes scabra, S. hamata, Gliricidia sepium, Arachis pintoi, S. guianensis, Lablab purpureus, Megathyrsus maximus*, *Pennisetum purpureum*) to name a few.

Tropical forage germplasm collections contain more diversity than any other crop or forage collection in terms of numbers of genera and species. As in all forage collections, grasses (Poaceae) and legumes (Fabaceae) dominate and for the tropical collection, all three legume subfamilies (Faboideae, Mimosoideae and Caesalpinioideae) are represented, although the most prevalent is Faboideae. The collections contain about 600 recognised genera and most of those are represented by more than one species. ILRI reports it alone has ~ 1400 species in its collection.

There is also diversity in form. While herbs dominate, climbers, shrubs and trees are all represented; each form by several species.

Why do we need a strategy?

Loss of habitat: Many of the accessions currently held *ex situ* are from regions that have undergone significant land-use change over the past 50 years. The urban expansion in South and Central America has seen forests, grasslands and savannahs replaced by urban space. The expansion of agriculture, especially in Brazil, has resulted in vast areas of natural forests and grasslands being substituted by intensive production of crops such as soybean and improved monospecific pastures. There are ~ 60 million ha of *Brachiaria brizantha* cv. Marandu in Brazil, which is a dangerously narrow genetic base highlighting the importance of germplasm diversity. Similarly development and population growth in many parts of Africa have resulted in expansion of cropping and overgrazing of rangelands with associated loss of biodiversity. The changes in the economies and populations across the tropics have made the TSTF germplasm already held *ex situ* extremely valuable (sometimes irreplaceable) and in need of a particular focus on conservation.

Crop wild relatives: TSTF collections contain several species that can be considered crop wild relatives. Some are wild types of the same species as major crops (*Vigna unguiculata* for instance), but in others the relationship among the forage collections and crops sometimes requires a more detailed understanding of taxonomy and species relationships. For instance the genus *Rynchosia*, and until recently, the genus *Atylosia* (now *Cajanus*) are both relatively close relatives of pigeon pea (*Cajanus cajan*). Before such genetic material can really be expected to contribute to crop plant improvement, there needs to be easier and better access to information on what genetic material is being held, and where. This will require better and more accessible genebank operating systems, sharing of information, and more attention to characterisation. These are the starting points to enable plant improvement programs to access genetic material that many crop breeders probably do not even know exists.

Decline in resources: TSTF and their conservation have seldom had the priority of most crops. Investment in both conservation and utilisation of TSTF has declined since about the 1990s. This has occurred in even the most developed countries that have achieved significant production and economic benefit from TSTF, such as USA, Australia, South Africa and Brazil. The decline in investment over the past 25 years is evidenced in many ways; poor viability of collections, fewer staff and resources, loss of expertise, use of old and outdated genebank operating systems, and the vulnerability of root nodule bacteria (RNB) collections that were assembled alongside the acquisition of legume collections. A strategy, which can articulate both the value of TSTF and the need to conserve and undertake research of forage species for utilisation is an essential part in the bid to convincing policy makers, donors and managers that investment in genetic resources of TSTF is not only sound policy, but an essential one for food security, enhanced livelihoods and environmental benefits.

Reduced capacity: The decrease in TSTF investment in conservation and utilisation has reduced global capacity. Up until the 1990s, CIAT, ILRI, CSIRO Australia, EMBRAPA Brazil and other institutes employed in excess of 250 TSTF scientists. That number of active, employed forage scientists is now probably < 30 and the bulk of the knowledge built up over many decades now rests with about ~ 40 mostly retired scientists. A strategy towards conservation and utilisation must include a plan to rebuild capacity across the globe not just in the conservation of the collections, but also in their use across various agro-ecological zones, production systems and livestock species.

Exceptional diversity: ILRI reports about 600 genera and 1400 species in its collection, while CIAT holds about 730 species (Jean Hanson and Daniel Debouck 2015 *pers com*). There are certain other taxa in national genebanks that are not represented in either ILRI, CIAT or ICRAF. The preservation of this exceptional diversity necessitates genebank managers and researchers keeping abreast of a wide span of matters, from several technical issues to the continuous changes in taxonomy. Technical issues that are most critical in conserving these large and diverse collections include viability testing, seed dormancy, seed longevity, security backups, pollination and pollinators, diseases, day length sensitivity, ploidy levels and the wide range of breeding systems.

While there is much diversity, < 100 species have proven to be useful as forages (see for instance the species listed in SoFT (Cook *et al* 2005) that comprises ~170 species of which a significant number are of “potential” or marginal value. This means that globally, 1200 species of limited or no immediate forage, feed or environmental value are being conserved. This does not mean that 86% of the accessions held are of limited value. The largest collections of any one species are mostly those of that perceived to have had the greatest potential value and hence, most plant collecting focus. This is reflected in CIAT’s genebank where 45% of CIAT’s total forage accessions of ~ 730 species, are from just 20 species (Daniel Debouck 2015 *pers com*)

New opportunities: Bioscience technologies have dramatically advanced in recent decades, providing much better access to the understanding of the vast genetic diversity held in collections of many crop and forage plant species and their wild relatives. Exploitation of this diversity to overcome climatic, edaphic and biotic constraints is now possible supported by the explosion in “omic technologies” that have provided the capabilities to enable us to characterise the genetic variation more carefully. Nevertheless, it should be recognised that useful outcomes from applying “omic technologies” depend on the knowledge generated by adequate phenotyping and understanding of adaptation and utilisation.

Utilisation and seed availability: The best impacts from TSTF are achieved by ensuring well adapted forages are used. With so many species and genotypes proven to be useful in particular environments and systems, livestock production research and development programs need to be able to access the best advice from TSTF specialists and from selection tools (e.g. SoFT- Cook et al 2005). However selection of well-adapted germplasm needs to be followed by ready availability of viable seed (or vegetative planting material) in sufficient quantities to enable projects to progress quickly to evaluation and use at scale. A TSTF strategy must aim to provide pathways that enable the best germplasm to be selected and aim to provide options for ready sourcing of seed and planting material.

The role of the CGIAR: The CGIAR genebanks have a special place in TSTF collections. They are the largest, and their collections amongst the most diverse. They also provide (limited) backup storage for other collections and are better resourced than many national systems. They also have a mandate to conserve germplasm and supply material to users globally. However, there is evidence that CGIAR centres are being drawn into strong regional focus due, in part at least, to issues of awareness and location. CIAT reports that 43% of samples distributed in the period between 2005 and 2014 went directly to farmers and 33% were distributed within Colombia. A further 38% were distributed into other countries of LAC. ILRI has a different distribution profile. Only 9% of samples from ILRI went directly to farmers, while about 65% of samples went to NARS. About 70% of samples distributed have gone to SSA (most of these would have been to East Africa).

It is telling that for both ILRI and CIAT, only about 5-10% of distributed material went to South and SE Asia. This might be influenced by the many years that Asia was strongly supported by the Australian Tropical Forages Genetic Resources Centre (ATFGRC), which was closed in 2001 and the successful CIAT-based research and development program in SE Asia, which was more or less at its peak during the 1990s. Subsequent Australian centres that held the TSTF collection have had far less engagement (and capability) with respect to Asia; and while CIAT and the CGIAR remain engaged in TSTF research and development in Asia, the level of activity has undoubtedly decreased. Notwithstanding this history, the fewer interactions between the CGIAR centres with Asia are almost certainly influenced by location of the TSTF genebanks and their teams and the understandable tendency for them to be more engaged in their own regions.

The current proportion of accessions and samples from the CGIAR centres going to West and Central Africa, an area of high need, is relatively small, and are mostly included in the ILRI SSA figures (Jean Hanson 2015 *pers com*). Despite previous high profile ILRI-based TSTF programs in this subregion, especially those in Nigeria, the current level of TSTF research and development does not reflect its potential in improving livestock production and mixed crop-livestock systems in that subregion.

The CGIAR TSTF centres operate independently and do so partly as a result of history, although there is a long history of collaboration, which has been enhanced since the implementation of the CGIAR reform process. Nevertheless there is significant independence which no doubt has been justified in the decades of strongest regionally-based TSTF research and development activity. However, a much-declined skills base, especially with respect to utilisation, a reduced resource base together with increasing demand for livestock products and forages across livestock systems in the tropics highlights the need for efficiencies and more effectiveness. The trend that CIAT and ILRI have towards regional focus suggests a need to reconsider their roles, goals and priorities.

The ILRI genebank has commenced such a regional focus already with their research on breeding for disease resistance and greater utilisation in Napier grass (*Pennisetum purpureum*), diversity in *Pennisetum ciliare* (buffel grass) and the diversity and role of dual purpose legumes, especially cowpea. Today, however, the combined resources of all CGIAR centres probably do not have the technical skills that would enable them to cover the full range of priorities and needs. Efficiencies in management should provide a more comprehensive and unified strategic position for the CGIAR.

Tropical forage species and the ITPGRFA: The great majority of TSTF are not listed in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA). The collections in the CGIAR are managed under Article 15 of the ITPGRFA and may be made available under the standard material transfer agreement (SMTA). The exchange of material from national collections can be constrained because countries can be reluctant to share their germplasm with others outside of the multilateral ITPGRFA agreement. It is relevant to note that the vast majority of TSTF germplasm was collected prior to the Convention on Biological Diversity (CBD) coming into effect in 1994, so that most germplasm held outside of the CGIAR genebanks could in fact be exchanged without Treaty obligations. This is an important issue for conservation, but possibly more so for utilisation. A TSTF strategy needs to be developed cognisant of most species not being listed in Annex 1 of the ITPGRFA and the consequent concerns of governments in sharing national collections, the SMTA-related constraints applying to germplasm held in, and distributed from CGIAR collections, and the additional value of genetic material collected prior to 1994 and not held by CGIAR centres.

Summary: There is a clear need for a more coordinated, rationalized approach to TSTF conservation and use within a global community of international and national genebanks and their key users in order to maximise the representation of diversity and conservation of healthy germplasm in genebanks and to encourage its greater use. This strategy document aims to stimulate change and proposes a set of next steps and longer-term objectives.

Approach

Development of the strategy has been supported by three activities. Discussions were held with national and international genebank managers between April and June 2015 to gain their views on what needed to be considered in developing a TSTF strategy. A survey of key national TSTF Genetic Resources Centres (GRC), and the international centres, CIAT, ILRI and ICRAF was conducted in August 2015. The national GRC included those from Australia, Brazil (several), Kenya, Mexico, South Africa and the USA. The subregional centre operated by SADC in Zambia also contributed (Annex 1). The key findings from that survey are listed in Annex 2.

Finally, a workshop of genebank managers and forage specialists (Annex 3) was held at the GCDT headquarters in Bonn, Germany in October 2015 where a range of issues, including those raised in the survey, were discussed and where priorities were identified for inclusion in the strategy. Preparatory documents were distributed prior to the workshop.

A strategic plan

Tropical and sub-tropical forages may have a greater need for a comprehensive strategy than many other 'crops'. TSTF have attracted less attention because they are not usually regarded as a commodity in themselves, they are made up of a large range of species and significant components of the global collections are being conserved in poorly resourced GRCs in developing countries. They also have particular biological challenges such as breadth of breeding systems and seed dormancy that are critical for their conservation and utilisation but have become more difficult to address by the recent (20-30 years) history of reduced resources. The need for a strategy is strengthened further by the broadening role of TSTF beyond livestock feed to environmental uses such as control of soil erosion, green manure crops and sources of biomass for biofuels.

A strategy needs to be developed through a pragmatic lens. It has to be achievable and the transition from strategy to action needs to have a specific timeframe (5-10 year period). Most importantly, the implementation of the strategy should be monitored and evaluated at frequent intervals. This strategy document takes account of the most urgent issues while building towards a longer-term horizon. It has to be recognised that this will take many years to be achieved. However, it cannot be achieved without first rebuilding community, value, capacity and efficiency.

The issue of conservation and utilisation of legume root nodule bacteria, and its place in the strategy warrants particular mention. Almost all of the components of the strategy outlined below are relevant to RNB conservation. The survey revealed that there is probably only one, or possibly two dedicated TSTF RNB collections being maintained globally (Annex 2). There are two possible options for these collections. The first would be to assume that tropical legume development for agriculture and environmental benefits will depend only on promiscuous legumes and as a result, the RNB collections have little future value. The alternative is to consider that legumes that require specific RNB strains for effective nodulation have a potential value that warrants their conservation. The issue of RNB conservation and utilisation should be considered under all appropriate components of the strategy outlined below.

The strategy has three Objectives:

1. **Rebuilding the community of TSTF genebanks and genebank users to develop closer collaboration and trust;**
2. **Take steps to ensure more efficient and rationalized conservation within and between genebanks;**
3. **Actively support utilisation by anticipating germplasm needs and responding more directly to users' requests for information and seeds.**

Rebuilding community

1.1 Community: Establishment of a network of the TSTF community. The workshop identified the need to re-establish a TSTF community as one of its major priorities. TSTF germplasm is held by many national and three international genebanks. Without strong relationships between these, many of the key initiatives that comprise the strategy will be difficult to put into operation. The purpose of the community will be to encourage transition from individual and independent TSTF genebanks towards a network that knows the work and actions of members, can use network information to help set their own priorities, can form the basis of exchange of information and germplasm and for developing capacity. Overseeing this rebuild will require a dedicated role. As a first step the CGIAR will finance an experienced TSTF consultant through the "CGIAR Research Program (CRP) for Managing and Sustaining Crop Collections" (the Genebanks CRP) for one year to undertake a set of concrete actions (Annex 4) that will facilitate the implementation of the strategy and greater cooperation between CGIAR centres and between the CGIAR and key national genebanks.

1.2 Community: Communication. Communication is the cornerstone of any network. The strategy will publish a quarterly electronic newsletter that will focus on activities in the partner institutes, their achievements and impacts. The production of the newsletter will be the responsibility of the consultant, but all workshop participants have agreed to contribute. The newsletter will seek to include information from all national, regional and international organisations.

1.3 Community: Agreement on placing taxa into a standardized scale of priority. A key part of the strategy is to develop a common list of the taxa that are considered to be the highest priority. What taxa are considered important will vary between regions, environments, and farming systems; so development of the list needs to be carried out as a community initiative. Even if particular taxa are not highly regarded in one region, the priority list would alert other genebanks that some material held by them is a priority for someone else. Again, this would be a task for the consultant to coordinate (see 2.1). The prioritisation will purposely channel resources to taxa of high potential and away from other taxa that are proven to be less promising. The assumption is that lower priority taxa may be archived or even conserved by other institutions (e.g. the Millennium Seed Bank).

1.4 Community: Capacity strengthening. The decline in capacity in TSTF research is global and must be addressed. However, so much capacity strengthening is required that no one action or short-term program will deliver the capacity required in a five year period. Rather, the community needs to agree and plan what the priorities are and work to take advantage of opportunities as they arise. International Grassland Congresses (IGC) represent a forum that could be used as a catalyst for capacity strengthening workshops or tours, and there would undoubtedly be other such conferences and workshops that could play a similar role. There are other training opportunities (global and regional) that arise from time to time (training on the use of GRIN-Global for instance), and it should be possible to arrange workshops on the use of Software such as SoFT. The community should seek to develop a calendar of capacity strengthening opportunities that can be used to slowly rebuild capability.

Efficient conservation

2.1 Efficiency: Prioritisation. The large number of taxa making up the global *ex situ* TSTF collections coupled with acceptance that a majority of taxa does not have particularly high potential forage value, points to opportunities for efficiencies through prioritisation. The aim should be that all taxa and accessions be conserved. However, limited resources dictate that genebanks, and global TSTF specialists, should be prioritising to get best use of resources. Lower priority material would include those taxa of low potential forage or environmental use, AND accessions of taxa where evaluation, cultivar development and commercialisation has taken place (and in which there is currently no longer a program for further cultivar development) (Figure1). The highest priority germplasm would be those taxa that are considered to be most likely to deliver cultivars in the near and medium future (Figure 2). This prioritisation would help set priorities for characterisation, plant collecting, seed viability testing and seed increase. Prioritisation activities would include prioritisation within the RNB collections.

2.2 Efficiency: Active duplication and redundancy. The survey and the workshop discussions confirmed there are a significant number of duplicate accessions in the global system. These duplications might have arisen from various means. Some are accessions that have been acquired multiple times through exchange. There are also cases where large scale exchange of material has been undertaken for various reasons. The Australian collection has been sent to ILRI and/or CIAT and so this collection is held by at least two international centres. A significant proportion of the germplasm held by CIAT is also held in two or more genebanks (Australia, Brazil, USA or ILRI) as a result of joint collecting missions. Some of the South African grass and legume collections are held in the Australian collection.

Other duplicates have arisen from plant collecting missions to the same populations multiple times, usually because those sites and populations have previously yielded promising germplasm. There are also cases where smaller national genebanks are maintaining germplasm received many years ago from another genebank and are continuing to maintain this material even though it is no longer considered a source of forage development in that region.

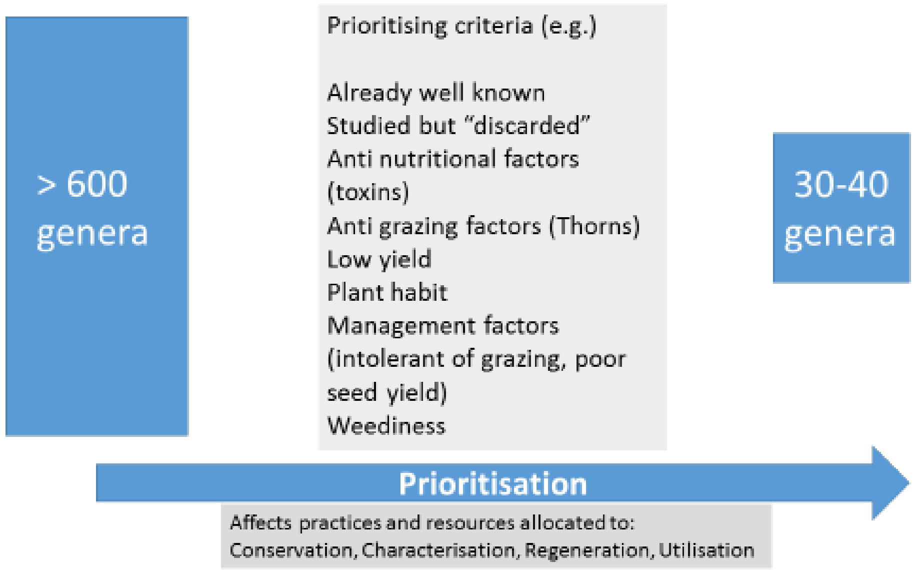

Figure 1. Diagram of possible prioritisation of genera and species to numbers that will enable better focus on conservation and utilisation of taxa more likely to contribute to livestock production and environmental benefits.

It can probably be assumed that some thousands of accessions are being held in "active duplication" as an informal "back up" around the globe. Given that exchange of germplasm in TSTF has been quite active since the 1950s, this is not surprising. It is acknowledged that duplicates are not always a bad thing. There are situations where holding germplasm in different geographic regions can overcome biosecurity barriers. There are also issues of material being held in national genebanks that would not be able to be acquired again because of ITPGRFA or biosecurity considerations. Nevertheless, there are efficiencies which can be accrued through due consideration of active duplication. Regeneration is a major cost of genebank operation and, while removing duplicates from collection might only cut the overall accession numbers marginally, these are amongst the easiest efficiencies to be had.

2.3 Efficiency: Safety backup. History has demonstrated that GRCs holding TSTF in particular, can be vulnerable to changes in government, institutional policy, donor and private sector short-term priorities, and political unrest. The question of vulnerability is possibly greater in TSTF because they are neither a commodity nor staple crop.

This is not just an issue for developing countries. For over 30 years, Australia has struggled with issues of crop and forage plant genetic resources and their conservation. It has recently put into operation a new plan to consolidate PGR centres in general, including forages, but that plan is considered by many to be much under-resourced. South Africa has very valuable TSTF germplasm, but over the last decade it has significantly reduced support of its conservation. Valuable collections in the USA and Australia have been lost through the failure to deal with conservation of accessions on the cessation of active programs. Similarly, Brazil has been reducing its investment in TSTF PGR conservation.

In short, there can be no absolute confidence that germplasm held in any particular organisation will be maintained for even the medium term (10-30 years). Consequently, there needs to be a process to systematically assess, implement, and document backup strategies.

The results of the survey point to the need for a prioritised focus on safety backup. A significant number of respondents reported that < 10% of collections were backed-up in other institutes, national or international. Others, such as the USDA, CIAT and Australia reported > 75% of material backed up.

Securing safety backup of TSTF will be challenging and requires a systematic evaluation of the issues and options including prioritisation of species. Rather than attempt to immediately initiate the transfer of material for secure backup, it would be more efficient and effective to assemble information of what species and accessions are being conserved and where, what duplicates are being conserved and an overall picture of viability of those accessions. From that information it should be possible to develop and implement a safety backup plan based on the aforementioned species prioritisation.

2.4 Efficiency: Core collections. Establishing core collections can contribute to efficiencies through having an evidence-based selection of accessions representing key diversity of a particular species. Such cores, especially of prioritised taxa can form the basis of utilisation and conservation efforts. This has already been done in some TSTF species such as *Desmodium ovalifolium, Flemingia macrophylla, Lablab purpureus, Stylosanthes capitata, Stylosanthes macrocephala* and *Stylosanthes viscosa.* While actual core collections might not have been identified in other species, published diversity studies for species such as *Arachis pintoi*, *Bothriochloa* spp., *Centrosema* spp., *Desmanthu*s spp., *Megathyrsus* spp., *Rhynchosia* spp., *Stylosanthes scabra*, *Pennisetum* spp. and *Urochloa* spp. would enable cores to be identified relatively easily. Determining core accessions would enable genebanks to better apply resources for seed regeneration and subsequent distribution.

Other types of TSTF "cores" could be defined by selecting best-bet accessions across diverse species that are likely to be adapted to both particular agro-ecologies and uses. Such ago-ecological cores are considered under 3.1.

2.5 Efficiency: Ensuring conservation of priority germplasm. While most responses to the survey reported that > 50% of their collections had acceptable viability, a number of genebanks such as those of Brazil, Kenya, South Africa and Mexico reported that <50% of their collections had acceptable viability. In some rare examples, that figure of accessions with acceptable viability was <25%. It would be inefficient to attempt to regenerate all the germplasm under threat. Some of the "low-viability" material will be held elsewhere and possibly in a better state of health. Also, some of the low-viability material will be in low-priority taxa. While regenerating low-potential taxa should remain an aim, the priority should be to ensure conservation of higher priority taxa. For example, South African collections have accessions of *Vigna unguiculata* collected from semi-arid and even arid regions of that country. That material has probably not been shared with other genebanks and, if it is in a vulnerable state, it ought to be regenerated as a matter of urgency. A critical first action in implementing the strategy should be to begin assembling a comprehensive list of what germplasm is held in what centres, and what condition those collections are in. This action is critical as it underpins all of the "efficiency" and "utilisation" components of the strategy. The consultant will have to facilitate this process, which will need to be implemented in parallel with the prioritisation of germplasm (see 2.1).

2.6 Efficiency: Characterisation. Characterisation of TSTF includes phenotypic, genetic and, in some cases, nutritional studies. Given the breadth of plant forms, there is not one standard set of descriptors and, in fact, most characterisation has been undertaken using attributes selected to define diversity in a particular species. The large amount of characterisation data noted in the survey should be assembled as soon as possible. Some of this characterisation information has been published, but mainly in summarized form and not by accession, except for Australia's discontinued series "Genetic Resources Communication (GRC) series". There should be a commitment to assemble these data so they are preserved for future use and, where possible, take advantage of the policy of the journal *Tropical Grasslands-Forrajes Tropicales to* revive the tradition of GRC publication of diversity studies. Given the diversity of attributes, it is recommended that the data be only assembled in the first instance and <u>not necessarily collated in any one databases at this time</u>. Care should be given to ensuring authorship/ownership of data is acknowledged. Where possible, the data could be made available in a raw form on a shared website (potentially hosted by the GCDT).

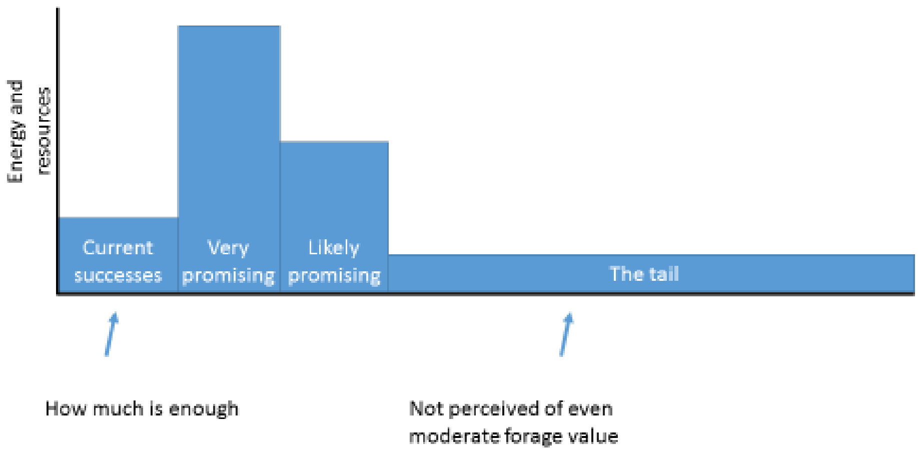

Figure 2. Scheme of possible prioritisation and its impacts. Current successful taxa such as *Urochloa decumbens* and *Stylosanthes scabra* would be conserved as a priority with an expectation of future need; very promising and likely promising taxa would have the greatest focus with respect to diversity, characterisation and evaluation (e.g. *Mucuna pruriens*, *Pennisetum* spp., *Desmanthus* spp.), while the majority of accessions would be conserved and regenerated at the lowest priority.

2.7 Efficiency: Documentation systems. The survey revealed a wide range of documentation systems being used. These included Oracle, FoxPro, Access, Excel spreadsheets, and GRIN-Global. Both CIAT and ILRI are considering transferring to GRIN-Global in the near future. Encouraging the transfer from the current operating systems to GRIN-Global is a core action under the strategy. Moving towards a uniform operating system should facilitate the sharing of data and that single outcome would underpin many of the efficiencies in regeneration, duplication and safety back up. A key commitment of the strategy is that the GCDT will provide technical advice and support to national and international centres to encourage and facilitate widespread adoption of GRIN-Global.

2.8 Efficiency: The CGIAR system. The CGIAR has 3 centres that conserve TSTF. The CIAT collection is the largest. It is based in Cali, Colombia and has had as its focus the assembling, conservation and study of species adapted to acid, infertile soils of tropical and subtropical LAC. It has been a major collector of legume germplasm from LAC and SE Asia and has assembled a large collection of a few African grasses, such as *Urochloa* that play major roles in regional production systems. ILRI's collection, based in Addis Ababa, Ethiopia is slightly smaller and has focussed on sub-Saharan germplasm, especially grasses such as *Pennisetum* spp., but has substantial collections of legumes from LAC. ICRAF's collection is the smallest and is focussed on tree and shrub species, mostly legumes. There is some overlap (duplication) of germplasm between the CGIAR centres and it should be noted that both ILRI and CIAT hold significant collections of legume tree and shrub species (*Cratylia* at CIAT for instance, and *Sesbania* at ILRI). The three centres use different operating systems and have regeneration and other conservation practices independent of each other.

Having centres in both South America and Africa has advantages. It should enable germplasm to be acquired more easily and quickly from users in the same region, for instance, and it may reduce constraints in germplasm exchange associated with biosecurity risks and, in particular, the concern of plant quarantine authorities regarding introduction of germplasm from other continents and countries.

However, those regional advantages are secondary to the system-wide benefits of closer alignment between CGIAR centres and, preferably, having all three operating as one. Those benefits are strategic and operational and, importantly, reduce one of the major risks of the current model of independent CGIAR TSTF genebanks as elaborated below.

Amalgamation of CGIAR TSTF centres would provide strategic advantages with respect to policy and overall leadership in TSTF decision-making within a CGIAR system that has migrated to multi-institutional CRPs. These CRPs have the responsibility of setting outcome and impact priorities and goals across the CGIAR. Focussed CGIAR-wide relationships between genebanks and particular CRPs such as those associated with livestock and environmental issues are vitally important in underpinning research for development outcomes in socio-economics, environmental and crops and livestock production.

Amalgamation would also have many operational benefits such as a single set of priorities, reduced duplication of conservation, especially with respect to regeneration practices, and one unified management and documentation system.

Amalgamation also provides a means of addressing a major risk for the CGIAR TSTF system, and more importantly, the global system. The current CGIAR model has never addressed the key issue of maintaining knowledge and ensuring and implementing succession planning and security with respect to genebank managers and management. The ILRI and CIAT genebanks, in particular, have to a large extent each had the same two genebank managers for more than 20 years; a fortunate situation that is unlikely to be repeated. These leaders have a wealth of TSTF technical and "institutional" knowledge, which would be largely lost on their departure. Having a single centre with at least two senior positions, albeit with different roles (e.g. senior management/external, and technical oversight) would be a far less vulnerable model for the CGIAR, and for the global TSTF community.

Utilisation

3.1 Utilisation: Knowledge and skills. Three particular but linked factors make the role of genebanks and genebank specialists more critical in the path to impact of TSTF than crops. While most crop species have a clear differentiation between conservation of germplasm and breeding program and subsequent utilisation, that differentiation is less obvious or is, indeed, absent in TSTF.

- TSTF are seldom a commodity in themselves even though they are a key component of many livestock production systems in the tropics and subtropics. Not being a commodity means that there is no commodity value chain and a R4D discipline/community that is directly demanding new products. By comparison, crops such as groundnut have national/private sector bodies that can articulate clearly defined needs such as disease resistance, and can take ownership of implementing adoption and impact. TSTF are just one component of livestock value chains, which are frequently dominated by other factors such as animal genetics and livestock disease management.
- Similarly, TSTF do not, in the main, rely on breeding programs, but rather use wild material directly and even other feed stuffs for animal nutrition. Therefore, the path to impact in TSTF is seldom via a breeding program that would be focussed on delivering better varieties of a species that is already in use. This means that the GRCs are the direct suppliers of germplasm that will be used in research and development. Evidence for this includes the growing number of farmers who are direct recipients of seed samples from CIAT's genebank.
- The scarcity of skills and capacity in TSTF demands that GRCs are the knowledge source for research on its conservation and diversity, and on its use in development. R4D programs are often in need of well-adapted forages but have no knowledge themselves of TSTF, their adaptation, potential, and management needs. As such they rely on GRCs to select the most likely germplasm for environments and farming systems. This does not often happen in other "crops".

To address these issues, it is essential that GRCs build their knowledge base so that they can provide the best advice and seed for R4D. The knowledge can be made available to some extent through various tools. ILRI and CIAT have developed tools that can estimate feed and forage needs within systems and map required forage calendars (e.g. FEAST (Duncan *et al* 2012)). The IAT model (Lisson *et al* 2010) similarly enables users to compare feed supply and feeding strategies to deliver particular outcomes (preferential feeding to females for better reproduction for instance). SoFT (Cook *et al* 2005) is a selection tool with a database, which nominates a suite of elite species, cultivars and accessions that will be best adapted to environment X farming system combinations. In this way, SoFT provides what is essentially a "core collection" of best bet accessions.

However, tools themselves are not the best source of knowledge. Experienced forage specialists are needed to interpret the recommendations and fine-tune management. These tools reflect past knowledge and do not address the issue of fitting known germplasm into new situations, or seeing the opportunities for new germplasm in existing environments and systems.

The future of livestock production and environmental management in the tropics and subtropics is very much dependent on building new skills and expertise in tropical forage science. This is a longer-term goal but can be commenced now through the community focus outlined above. Opportunities to build capacity could be sourced through various donors and opportunities. The next IGC, probably in Nairobi, will undoubtedly bring forage specialists together, and it would be a relatively simple task to add on a 3-4 day workshop run by experienced TSTF specialists. A more immediate response for renewed skills and updating knowledge is through updating tools which provide the foundation knowledge of TSTF adaptation and management. It is now > 10 years since the release of SoFT and an update to capture the last 10 years of TSTF science is urgently needed. There is also an urgent need to ensure that the role of SoFT and its contribution is more widely appreciated. There remain too many examples where forage species being selected and tested in research and development projects are not suitable for their proposed use, and where material which would be well adapted is being overlooked.

3.2 Utilisation: Path to impact. The decline in investment in TSTF has been in response to the perception, real or not, that conservation of TSTF is costly, and has not been a vehicle for influencing change in production and livelihoods. This is despite many examples from around the world where TSTF have transformed production systems and people's lives (Shelton *et al* 2005, White *et al* 2013). The TSTF community has contributed to this situation in some way by not placing sufficient emphasis on its successes, by focusing on the diversity of germplasm and the complexity in managing it and not focussing on their roles and partnerships in taking elite germplasm to utilisation and subsequent improvements in livelihood and environment. Under a well-resourced plant genetic resources environment, it may well be preferable for resources to be focussed on conservation, but under a more challenging funding environment it is important that PGR are providing the knowledge and emphasis that users need and shift their emphasis towards utilisation (see Figure 3).

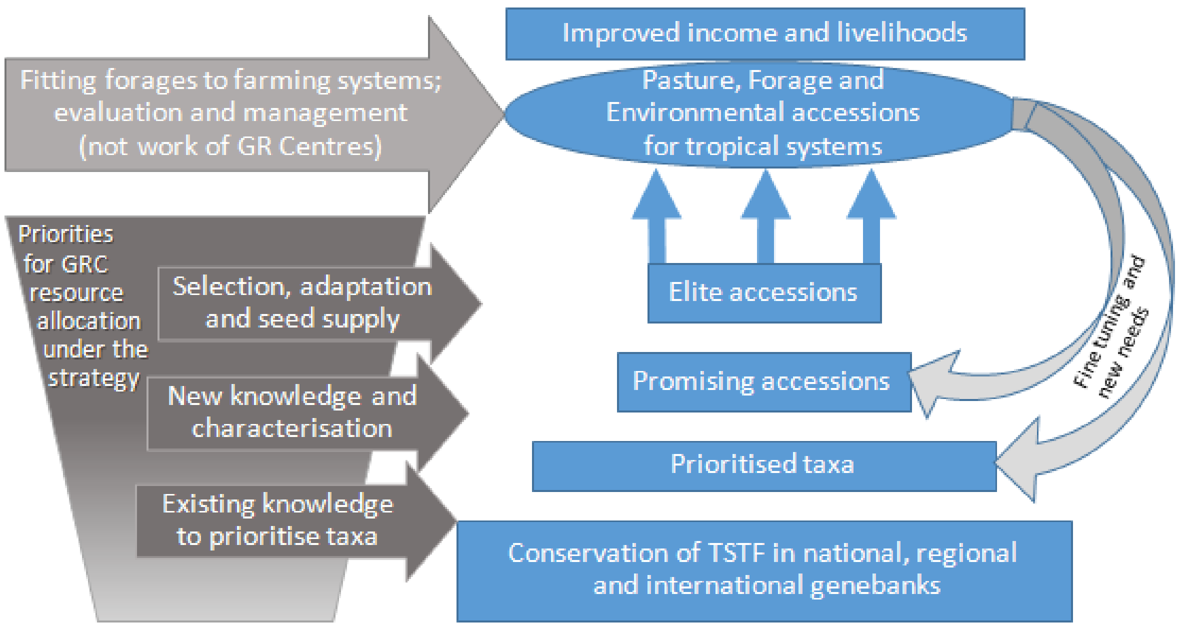

Figure 3. Path to impact for TSTF from conservation through to improved incomes and livelihoods. Note that the Genetic Resource Centres would expand their focus to their own research and that of others to identify and supply seed or planting material of elite accessions. They may partner in research on utilisation (Fitting forages to systems) but that would not usually be a prime role.

3.3 Utilisation: Seed supply. In the absence of breeding programs and TSTF species industries in most countries, there is a major bottleneck in the path to impact if seeds of elite germplasm are not available for R4D or even development projects. Typically, genebanks are charged with supplying small amounts of seed for research, perhaps 40-100 seeds. To take these few seeds to the amounts required for on-the-ground research takes at least 3 or, more likely, 4 years – longer if delayed by availability, quality, knowledge gaps, or biosecurity issues. This is the life of most R4D projects and so it follows that, unless larger quantities of seed can be supplied on request, then it is unlikely that elite germplasm will be available and adopted. What will be tested in research and development trials will be decided by seed availability (of often poorly adapted forages) with predictable poor outcomes for the research, and even more damage to the reputation of TSTF and their ability to contribute to production, livelihoods and environmental management.

The critical response to overcome this issue is for organisations to broaden their roles to include provision of seed of elite lines in sufficient quantities to transform the way forage R4D is being undertaken. An additional but aligned role for centres might be the maintenance of basic and pre-basic seed stocks of commercialised varieties.

Conclusion

TSTF are a key resource for current and future tropical agricultural systems and environments. Over 50 years of collection, conservation and research has built a wealth of knowledge and delivered major socio-economic impacts. Despite those successes, and the recognised need for even larger roles of improved forages in the emerging tropical agricultural systems, the past 20 years has seen a decline in effort in conservation and utilisation research of TSTF. The strategy outlined here provides a plan to efficiently and effectively meet the dual demands of conserving valuable material, and making elite germplasm available for use.

The successful implementation of the strategy will require the strong commitment and engagement with national, regional and international centres. While international centres are well established and often have greater available resources than many of the national centres, the latter probably have a growing role through their conservation and research on their regional forage species and through their deeper understanding of particular suites of germplasm that are best adapted to their regions.

Implementation of the strategy is a medium term goal of perhaps 5-10 years. However, a number of important components of the strategy can be implemented or at least be initiated by July 2017. Those “first-step” components provide the basis of a workplan for the GCDT consultant and the committed TSTF genebanks over that time (Annex 4). Successful implementation of these “first-step” components of the strategy and the emergence of TSTF genebank “leaders” will be key to determining workplans beyond 2017. It will also lay the foundations for defining how progress in implementing the strategy might be monitored and plans revised over the next decade, and importantly, provide a clearer view on how global TSTF conservation and utilisation might be supported in terms of leadership, resources and funding beyond the immediate plans.

Acknowledgements

The contribution of the many genebank managers who responded to the survey to TSTF forage genebanks and to the genebank managers and other TSTF researchers who participated in strategy workshop held in Bonn, Germany is gratefully acknowledged. Special thanks are due to Cristian Moreno of the Global Crop Diversity Trust for his support in developing the strategy through the design of the survey and the cataloguing and interpretation of the survey responses.

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Annex 1: Respondents to the survey conducted to assist the development of a strategy for the improved conservation and utilisation of tropical and subtropical forage germplasm.

Country	Genebank/Agency	Respondent	Email address	Main genera and species and other characteristics of collections
Australia	APG, SARDI, Adelaide	Mr Steve Hughes	steve.hughes@sa.gov.au	Large diverse collection of grasses and legumes based on discontinued ATFGRC
Australia	QDAF, Mareeba	Dr Kendrick Cox	kendrick.cox@daff.qld.gov.au	Elite subset of APG collection
Brazil	EMBRAPA (District Federal)	Dr Jose Valls	jose.valls@embrapa.br	*Arachis* and *Stylosanthes*
Brazil	EMBRAPA (Sergipe)	Dr Jose Rangel	jose.rangel@embrapa.br	*Desmanthus*
Brazil	EMBRAPA (Campo Grande)	Dr Cacilda Valle	cacilda.valle@embrapa.br	*Urochloa* (syn. *Brachiaria*) collection
Brazil	EMBRAPA (Planaltina)	Dr Marcelo Ayres	marcelo.ayres@embrapa.br	Tropical legumes general
Brazil	EMBRAPA (Campo Grande)	Dr Sandra Santos	Sandra.santos@embrapa.br	*Mesosetum* and *Paspalum*
Brazil	EMBRAPA (Campo Grande)	Dr Rosangela Simeao	rosangela.simeao@embrapa.br	*Stylosanthes guianensis*
Brazil	EMBRAPA (Sao Paulo)	Dr Alessandro Favero	alessandra.favero@embrapa.br	*Paspalum* spp.
Brazil	EMBRAPA (Minas Gerais)	Dr Juarez Machado	juarez.machado@embrapa.br	*Pennisetum purpureum*
Brazil	EMBRAPA (Campo Grande)	Dr Liana Jank	liana.jank@embrapa.br	*Megathyrsus maximus*
Colombia	Forage genebank CIAT, Cali	Dr Daniel Debouck	d.debouck@cgiar.org	Large diverse collection grasses and legumes - focus adaption to acid and infertile soils.
Ethiopia	Tropical Forages Genebank, ILRI, Addis Ababa	Dr Jean Hanson	j.hanson@cgiar.org	Diverse collection of grasses and legumes - focus on African germplasm
Kenya	Genetic Resources Institute, Nairobi	Dr Desterio Nyamongo	desterio.nyamongo@kalro.org	Large collection of mostly east African germplasm
Kenya	ICRAF forage collection, Nairobi	Dr Alice Muchugi	a.muchugi@cgiar.org	Tropical forage tree species
Mexico	INIFAP	Dr Francisco Villanueva	villanueva.francisco@inifap.gob.mx	Large collections of *Tripsacum* and *Leucaena*
Mexico	INIFAP	Dr. Francisco-Oscar Carrete-Carreón	focc1928@hotmail.com	Mexican Native Grass collection including *Bouteloua* spp.
South Africa	ARC, Roodeplaat, Pretoria	Mr Flip Breytenbach	FBreytenbach@arc.agric.za	Includes wild tropical grasses and legumes from northern (tropical and subtropical) semi-arid to sub-humid South Africa
USA	USDA Griffin Georgia	Dr Gary Pederson	gary.pederson@ars.usda.gov	Large diverse collection – key species include switch grass (*Panicum virgatum*), *Bothriochloa ischaemum*, *Digitaria eriantha, Desmodium* spp. and *Leucaena* spp.
Zambia	SADC Regional Genebank	Dr Lerotholi Qhobela,	lqhobela@spgrc.org.zm	Regional genebank for member countries of SADC with some forages maintained.

Annex 2. A summary of the results from a survey of national and international genebanks conducted to inform the development of a strategy for the conservation and utilisation of tropical and subtropical forage germplasm.

Responses: Responses to the survey came from the international centres, CIAT, ILRI and ICRAF and national genebanks from Kenya, South Africa, Australia, Mexico, Brazil and the USA (Annex 1). There was also a response from the SADC genebank in Zambia (SADC is a sub-regional organisation representing 20 countries in southern Africa). Brazil's response to the survey was via a number of individual genebanks in the country each of which have a focus on a particular taxa or region within the country. The key issues from the survey are summarised below.

Diversity: The survey confirmed the diversity of taxa globally. While some genebanks such as those of CIAT, ILRI and Australia held very diverse collections, others, especially national genebanks held collections which focussed on particular taxa, or germplasm for particular uses. USA and Mexico's collections held large collections of switch grass (*Panicum virgatum*) and *Tripsacum* spp. respectively as well as other sub-tropical species, and South Africa held large collections of *Digitaria* and *Vigna* spp.. The ICRAF GRC was the only collection focussing on tree species. Table x lists the reasons why particular collections were especially important or even unique.

Availability of germplasm: The survey revealed some alarming results. In some cases seed viability was <50%. In addition to suspect viability, availability of germplasm for exchange was further constrained by "legal" issues such as government policy and issues around the International Treaty on Plant Genetic Resources for Food and Agriculture, and the quantity of seeds available.

Backup security: While some genebanks (e.g. USA, Australia and CIAT) have their collections in backup secure storage, the majority don't. Some have < 10% of their collections backed-up (e.g. Mexico, Kenya and South Africa). The survey results reflect specific actions that genebanks have taken to ensure formal back up. There occur also "active duplications" that have eventuated through germplasm exchange or through joint collection missions where seed collected has been shared between parties; these collections entered independently as individual accessions into different genebanks and do not represent proper "backup".

Backup collections are held by a range of institutes and units. Some are held in the same country such as those of USA and Australia, but with one exception, there are few collections backed-up in international centres and, apart from the CGIAR centres, the collections have not been deposited in the Svalbard Global Seed Vault. This is a key challenge for the safe conservation of TSTF germplasm and needs to be addressed through the strategy.

Size of collections: The results of the survey regarding size of collection have some ambiguity as there is no definitive list of taxa that comprise TSTF. Nevertheless the survey provided valuable insights into collection size and diversity. CIAT's collection is about 23,000 accessions from ~ 700 species, ILRI's collection is 18,600 accessions from ~1400 species. Of the national collections, Australia's is ~ 13,000 accessions, and the USDA and Kenya collection both number ~15,000 accessions. Brazil's collection is about 9,000 accessions. Other national collections are smaller than those mentioned above. Some, and perhaps most, collections have particular germplasm which is rare or even unique. The Kenyan collection, for instance, holds large collections of both African and American material, the latter very likely to be subsets obtained from CIAT, Brazil or Australia. However, it is probable that the African material includes accessions that are unique.

Important species: Despite there being > 600 genera and probably > 1400 species in global TSTF collections, only about 30 genera were considered of the highest importance in terms of use and potential use. All responses indicated support for prioritisation of taxa as for more efficient and effective management of TSTF collections.

The differences in forage potential between various genera and species are the foundation for considering taxa differently in terms of their conservation, seed increase, and availability.

Importance of individual collections: There are a large number of reasons put forward to warrant the importance of collections. Some are related to a particular taxa or plant form such as *Arachis* and *Urochloa* in Brazil, and *Desmanthus* in Australia, tree species for ICRAF, crop wild relatives for USA. Some relate to the environment of the targeted region such as acid soils of LAC in the case of CIAT, while others highlight the origin of the collections (*Tripsacum* for Mexico and accessions collected in SSA in the case of ILRI). Notwithstanding the reasons put forward by the various genebanks, it is likely that there are many others that have not been highlighted. For instance genebanks may have critical germplasm that might not have warranted mention in the survey, but could be an important source of genetic material, or individual genebanks may hold much needed diversity in taxa, which are poorly represented elsewhere.

Skills: Few responders indicated that their genebanks had more than one or two staff who might be considered expert in TSTF, either in their conservation or utilisation. The exceptions included the USA, Brazil and Australia. Even the CGIAR reported limited staff and expertise. All respondents recognised the value of tools such as SoFT (Cook *et al* 2005) as being critical in supporting genebanks in selecting the best-adapted species and accessions for various environments and uses.

Characterisation data: Almost all responses to the questionnaire confirmed that characterisation data (phenotypic and/or molecular) are available for many species. These data collectively represent hundreds of years of research and are an important resource for developing the strategy and in developing core sets of material.

Rhizobia collections: The responses to questions on whether or not genebanks held or could access collections of root nodule bacteria (RNB) revealed that some had access to a few of the more commonly used strains and none conserved anything like a comprehensive collection. The response indicated that the only comprehensive collection of TSTF RNB was held at Murdoch University in Western Australia. Other research institutes have never established RNB collections, no longer have active collections (even if accessions are still being conserved), or in the case of the USDA, the collection is housed under another unit (USDA National Rhizobium Collection). The Murdoch collection was assembled over several decades by CSIRO and has fortuitously been conserved at Murdoch for the past decade. The collection is unique. A catalogue of the collection was published in 1998 (Eagles and Date 1998).

Operating systems and data availability: Operating systems used by national and international centres ranged from MS-Excel spreadsheets to MS-Access, FoxPro, Oracle and GRIN-Global. This plethora of operating systems, some quite old, together with lack of resources and policy issues regarding sharing of data has resulted in very few genebanks having data available to share with others. However, many responders acknowledged that these data, especially characterisation data, have not been added to the their own operating systems due primarily to the lack of resources or operating systems not being able to accommodate such data. Information contained in these databases range from passport over genebank management (e.g. field multiplication, seed stock and viability testing, seed health, seed distribution) to agro-morphological and molecular characterization, among others.

Annex 3. Participants at a workshop to develop a strategy for the conservation and utilisation of tropical and subtropical forages held at the Global Crop Diversity Trust, Bonn, Germany, October 2015

Name	Institute
Dr Ahmed Amri	ICARDA, Morocco
Dr Sammy Carson	ICRAF, Kenya
Dr Daniel Debouck	CIAT, Colombia
Dr PK Ghosh	IGFRI, India
Dr Luigi Guarino	GCDT, Germany
Dr Jean Hanson	ILRI, Ethiopia
Dr Chris Jones	ILRI, Ethiopia
Dr Charlotte Lusty	GCDT, Germany
Dr Brigitte Maass	University of Gottingen, Germany
Dr Cristian Moreno	GCDT, Germany
Dr Alice Muchugi	ICRAF, Kenya
Dr Desterio Nyamongo	GRI, Kenya
Dr Gary Pederson	USDA, USA
Dr Bruce Pengelly	Private Consultant, Australia
Dr Michael Peters	CIAT, Colombia
Dr Lerotholi Qhobela	SADC, Zambia
Dr Rainer Schultze-Kraft	CIAT, Colombia
Dr Jose Valls	EMBRAPA, Brazil
Dr Francisco Villanueva	INIFAP, Mexico
Dr Peter Wenzl	GCDT, Germany

Annex 4: Priority initiatives for 2016-17 as the first steps towards longer term implementation of the tropical and subtropical forages strategy. Details under each of these priorities are outlined under the relevant sections of the strategy document (pages 6-13).

1.1 Community: Establishment of a network of the TSTF community

1.2 Community: Communication

1.3 Community: Agreement on placing taxa into a standardized scale of priority

1.4 Community: Capacity Building

2.1 Efficiency: Prioritisation

2.3 Efficiency: Safety backup

2.4 Efficiency: Core collections

2.5 Efficiency: Assemble lists of germplasm held by genebanks, and its viability

2.6 Efficiency: Characterisation

2.7 Efficiency: Documentation systems

2.8 Efficiency: The CGIAR system