Future Generations – Will Any Be Lacking Tropical Forage Genetic Resources?

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Abstract
It's high time to stop talking about the (forage) plants and talk about the people. Three (Australia, India, USA) of the about a dozen curators of tropical and subtropical forage (TSTF) genetic resources collections involved in developing a *Global Strategy on Conservation and Utilization of Tropical and Subtropical Forage Genetic Resources* on behalf of the Global Crop Diversity Trust in 2015 have since retired. In all cases their replacements were not expert in this challenging commodity. Why? The commodity is highly diverse and requires understanding of a substantial body of knowledge generated over more than five decades. It requires a level of familiarity with two plant families, grasses and legumes, which comprise a plethora of genera and species. Some of these species, novel to agriculture, have been proven extremely useful for diverse livestock production systems, for environmental services and for people's livelihoods. Others are rather 'bycatch' from early exploration and probably don't deserve conservation at all, or at least at the highestgenebank standards. Why were there no mentored scientists waiting to take up the vacant positions? There is today a worldwide shortage of applied plant research capability as "–omic sciences" or modelling seem more appealing to emerging scientists. Few budding agricultural scientists want to dedicate their career to a commodity, which mostly ranks low in recognition of its science merits and funding support. At the same time forage science and forages are coming under greater scrutiny because of environmental factors, especially in relation to the impacts livestock production is having on global warming. However, there are emerging scientists wanting to build a career in tropical forage science. Unfortunately, they are often disconnected from similar work around the world, and their own work is insufficiently recognizedby aging, inward-looking institutions that still claim to lead global forage research and development despite the ever declining resources.

Background
"Apparently, the early phases of collecting and evaluation were much more valued than conserving and keeping the germplasm available for future generations"—twenty years ago, Maass and Pengelly (2001) recognized a drastic decline of interest in tropical and subtropical forage (TSTF) genetic resources after decades of pasture and forage research, particularly in Australia and tropical America. The lead TSTF research institutes of yesteryear have re-prioritized their research and development (R&D) programs with fewer and fewer requirements for TSTF germplasm from the collections in their genebanks.

This has occurred for several reasons. There is a view that the best-adapted species/genotypes for many of the tropical and subtropical production systems have been identified. Secondly, recent effort has been towards generating new diversity through grass breeding, particularly *Brachiaria*, in tropical America by the Centro Internacional de Agricultura Tropical (CIAT; now Alliance of Bioversity International and CIAT, ABIC) in Colombia and Embrapa, the national agricultural research organization in Brazil. Consequently, these institutions' research teams have been drastically reduced in number as illustrated by Maass and Pengelly (2001, 2019). Furthermore, teaching of TSTF sciences at universities has been under threat everywhere (Maass and Pengelly 2019) and fewer young emerging forage scientists are being produced.

The question arises: who will be the future user generation for the very diverse conserved TSTF germplasm?

Declining Deployment for Decades
A germplasm-based strategy for new forage development used since the 1950s gave impressive productivity gains in large areas of tropical grasslands, particularly in Australia and tropical America. Since the 1990s, the R&D focus has shifted towards long neglected crop-livestock systems, including those of smallholders in developing countries. As the best-adapted species/genotypes for many of these systems have been identified, today there is very little focus on germplasm characterization or agronomic evaluation to identify novel species or accessions.

Several large and highly diverse TSTF germplasm collections arose from extensive exploration of potential species (Maass and Pengelly 2019; Schultze-Kraft et al. 2020). These are being conserved at major national

and international institutions (Maass et al. 1997; Hanson and Maass 1999). A level of familiarity is required with two large and diverse plant families, grasses and legumes to manage this resource. It also requires familiarizing with a substantial body of comprehensive scientific and managerial knowledge that has been accumulated over more than five decades.

Twenty years ago, at the IGC in São Paulo/Brazil, Maass and Pengelly (2001) argued for more funding for TSTF germplasm and for better communication and networking among genebanks. They considered it crucial funding be improved before both germplasm and key knowledge was lost. Following that conference, a comprehensive database was established, which captured expertise from almost one hundred "experienced, often retired, forage specialists from across the globe". That database and selection tool was launched as the "Tropical Forages Database" in 2005; it has since been updated and made useable on tablets and smart phones and re-launched in 2020 (Cook et al. 2020). Yet, even such an apparently well-used database has not created greater germplasm demand. Requests for germplasm remain low and, in the absence of evidence that the genetic resource base is playing a useful role, it will remain difficult to convince anyone to support conservation in perpetuity. Prolonged lack of use will ultimately result in the loss of the resource itself.

Discontinuation of Capability and Skills

Karaca and Ince (2019) claim that "researchers and staff involved in germplasm conservation … are expected to have knowledge and experiences in a variety of fields including biology, molecular biology, molecular genetics, plant systematics, population genetics, plant pathology, plant physiology, plant ecology, biochemistry, computer science, legal science, economics, and political science"; but that few institutes could provide such comprehensive professional training and mentoring for genebank teams. Those authors recognized that "many researchers and staff working in genebanks since the 1970s have retired or will retire soon" and that useful knowledge and experience in germplasm conservation will be lost. This scenario has played out with three experienced national TSTF genebank curators (Australia, India, USA) retiring in 2015. The two leaders of the international genebanks (CIAT and ILRI) retired at about the same time. The impacts of losing these leaders is significant, but even more so if they cannot be replaced by well-mentored scientists due to inadequate financial resources and/or because such comprehensively skilled researchers are rare.

Facilitating Greater Utilization and Rationalization

Future Forages Users

When beginning to implement the *Global Strategy for the Conservation and Utilisation of Tropical and Sub-Tropical Forage Genetic Resources* (Pengelly 2015), the authors only met a small number of active forage R&D teams (Table 1), especially those in Argentina and Brazil. Only some of these teams were really connected to a genebank by making use of TSTF germplasm. Several were much more engaged in laboratory-based "–omic sciences" or modelling, which seem more appealing to emerging scientists. Further, the teams were not connected with each other, a fact that underlines clear need for active networking. The *Forages for the Future* newsletter (Maass and Pengelly 2016-2019) connected diverse R&D groups by reporting on the latest TSTF efforts and their impacts. This certainly created more recognition for the work of several emerging scientists around the globe. Nevertheless, there are only few budding agricultural scientists wanting to dedicate their career to a commodity that mostly ranks low in recognition of its science merits and funding support.

Conservation for Future Generations

Williams (1983) considered the range of tropical legumes for their potential forage value and suggested that 228 legume genera and 3,902 legume species were potentially of merit. The international genebanks of CIAT and ILRI have assembled a large proportion of these: 188 genera and 1,268 species and a similar number of grass genera and species. Many of these are nothing more than 'bycatch' from early exploration and probably do not deserve to be conserved for their forage potential. The *Tropical Forages Database* recognizes 172 entities (some of these are hybrids), but even that is probably massively optimistic. The reality is that ~30 TSTF species play a significant global role. This demonstrates that it is essential that genebanks with TSTF germplasm apply clear priorities to the species conserved and apply differential management based on those priorities. They need to focus their limited resources on what is important for future forage and environmental needs as current resource availability will not improve soon.

Future needs will be diverse but the following will be high amongst the many reasons why priority TSTF germplasm will play major roles:

- Impacts of emerging diseases or pests on used forages necessitating use of *ex situ* germplasm collection to select/breed for resistance;

- New plants required for farming systems that have to adapt to climate change impacts of temperature and water availability;
- New forage and pasture plants required for production systems that have to change because of their ecological footprint (non-climate change);
- Several priority species have little chance of recollection because widespread land use changes and habitat depletion have resulted in their near or total disappearance in environments of origin.

Table 1. Current situation of tropical and subtropical forage germplasm conservation, research, development and capability in selected countries/regions and future prospects

Country/region	Status of TSTF germplasm	Situation of forage research and development and capability	Prospects for germplasm use
Australia	Very large collection; largely duplicated with CIAT and/or ILRI; recurrent funding issues.	A new TSTF expert in charge of germplasm. No forages/grassland R&D program, institutionally part of ecosystem R&D.	No 'pipeline' for novel spp. or new accessions from collection exists.
Argentina	No national, only state TSTF collections; no international distribution. Risk of germplasm loss.	Resource country for some grass and legume spp.; countrywide active in forage R&D, focus on breeding, with several relative young people engaged.	Will continue to release TSTF cvs. adapted to some agro-ecologies; cv. use uncertain. Seemingly only small role for available germplasm.
Brazil	Large collection conserved centrally and in Active Germplasm Banks ('BAG' of Embrapa), partly with uncertain status; not available for distribution to other countries.	Very important as resource country for TSTF legumes; countrywide active in forage R&D, focus on germplasm and breeding, with several relative young people engaged.	Will continue to release TSTF cvs. adapted to various agro-ecologies for important livestock production. May tap available germplasm directly and for breeding.
USA	Large national TSTF collection, partly with uncertain status; distribution to other countries. Seemingly little connection to active forage R&D programs.	Lately more focus on native resources for diversifying grasslands and biodiversity maintenance. Some locally active teams (e.g. Texas, Florida).	Seemingly small role for available germplasm; no 'pipeline' seems to exist from germplasm collection to state programs.
Eastern Africa (Kenya, Rwanda, Uganda, Tanzania, Ethiopia)	Some collections, with uncertain status; high risk of loss. Probably low availability for distribution.	Active forage teams, but aged, only partly younger researchers involved. Underfunded TSTF R&D when considering the need.	Largely dependent on germplasm from outside; germplasm collections largely disconnected from TSTF 'real world'.
India	Two reasonable collections with uncertain status; distribution uncertain.	Large forage research team at IGFRI, relatively young, but high turnover of personnel, little long-term experience; active R&D programs.	Some use of available germplasm, but mainly breeding and –omics research. Germplasm collection seems disconnected from TSTF 'real world'.
China	National collection with focus on native forage resources, conservation status unknown; availability for distribution uncertain.	Unknown.	Unknown.
CIAT (now, ABIC)	Very large collection, partly duplicated with ILRI and/or APG; in principle free distribution.	Important resource; TSTF curator in charge of germplasm; little connection to forage R&D program.	Currently, most TSTF research in grass breeding; no 'pipeline' from the germplasm collection exists for new uses.
ILRI	Large collection mostly duplicated with CIAT or APG; in principle free distribution, but little availability according to international standards.	Regionally important resource; needs application of priority and differential germplasm management. Relatively young team with focus on diversity research.	Forage R&D program focused on genetic improvement; germplasm collection disconnected from TSTF 'real world'.

- * ABIC, Alliance of Biodiversity International and Centro Internacional de Agricultura Tropical (CIAT); APG, Australian Pastures Genebank; BAG, Active Germplasm Bank of Embrapa, Brazil; IGFRI, Indian Grassland and Fodder Research Institute; ILRI, International Livestock Research Institute; R&D, research and development; TSTF, tropical and subtropical forages.

Conclusion and Outlook

The authors have written many times of the parlous state of tropical and subtropical forage genetic resources. Not much has changed. This paper just repeats the arguments for the past 20 years.

Few budding agricultural scientists want to dedicate their career to a commodity that mostly ranks low in recognition of its science merits and funding support. At the same time, forage science and forages are coming under greater scrutiny because of environmental factors, especially in relation to the impacts livestock production is having on global warming. However, there are emerging scientists wanting to build a career in TSTF sciences. Unfortunately, they are often disconnected from similar work around the world, and their own work is insufficiently recognized by aging, inward-looking institutions that still claim to lead global forage research and development despite the ever declining financial resources.

If tropical and subtropical forage genetic resources are not worth keeping, then those global decision makers need to say so and, if they deem it necessary, decide what sort of effort should be made to keep the minimum. At the moment, the entire global TSTF genebank future seems to be destined to even more years of having limited resources and associated germplasm loss at scale. Those who have responsibilities need to recognize that, in the absence of decision making, future generations will not have access to even the highest priority germplasm. Genebank managers need to realize that they have to focus on the most important. Policy makers, such as those who "manage" the Biodiversity Convention and its implications, need to recognize that, insisting that all germplasm is important and must be conserved using the best of best of practices is being decidedly unhelpful.

Without significant change, the future generations of scientists or other users that the world needs to conserve and underpin utilization of tropical and subtropical forage genetic resources will not be attracted to engage. Decisions must be taken rapidly; otherwise it soon be too late.

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