Proceedings of the 9th International Conference on Agriculture, Vol.7, Issue 1, 2022, pp.10-20

ISSN 2682-7018 online
DOI: https://doi.org/10.17501/26827018.2022.7102

DISTRIBUTION OF COLLECTED AND CONSERVED SORGHUM (*Sorghum bicolor* (L.) Moench) LANDRACES IN SOUTH AFRICAN GENE BANK

Matelele LA *

National Plant Genetic Resources Centre, Directorate Genetic Resources, Department of Agriculture, Land Reform and Rural Development, Private Bag X973, Arcadia Pretoria, 0001, Republic of South Africa

Abstract: Plant genetic resources are a collection of potentially useful genetic material that is found both within and between certain taxonomies. A good understanding of their distribution is necessary to protect the plant genetic resources for food and agriculture. Understanding the locality of the collected and conserved sorghum landraces in South African gene bank's germplasm core collection is therefore critical. The study, therefore aimed at mapping and quantifying the geographic distribution of sorghum landraces in germplasm core collection of the South African gene bank from 1996 to 2008. 312 sorghum landraces were collected and conserved in South African gene bank between 1996 and 2008. The geographical location of 152 villages in 57 municipalities, located in 23 District Municipalities of six (6) Provinces, was used to generate a spatial distribution of Sorghum accessions. The sorghum collections in the South Africa gene bank core collection revealed an important dispersion, covering different geographic areas, with the majority (40.1%) of collections made in Limpopo Province for a period of 12 years. It was observed that in 2003, the sorghum collection increased by more than three time the initial collection in 1996. In contrast, there was a decreasing trend of sorghum collection observed between 2003 and 2008. Crop diversity may be necessary for future climate adaption, and its conservation is dependent on human activities and performance. The current analysis is also valuable in identifying collection priority locations, both explored and unexplored. Between 1996 and 2008, there were changes in the geographical distribution of sorghum germplasms in South Africa, which might be related to changes in climatic and agronomic conditions, the introduction of new varieties, and/or the development of new agricultural practises.

Keywords: plant genetic resources, geographic mapping, geographic distribution, sorghum

Introduction

The term "plant genetic resources" (PGRs) refers to the heritable traits present in and shared by plant species that have value for economic, scientific, or societal reasons. They comprise content thought to be of systemic significance and can be used in agronomic, morphological, biological evolution, physiological, biochemical, pathological, and ecological study and breeding, as well as weedy and wild relatives of cultivated crops (Ulukan, 2011). Furthermore, PGRs serve as the cornerstone of global agriculture and food security, particularly in light of the expanding human population. The significance

*Corresponding Author's Email: *LehlogonoloMA@Dalrrd.gov.za*

ORICD - https://orcid.org/0000-0001-8953-2561

of PGRs may be seen in every aspect of human activity since it provides a genetic resource from which improved and resistant varieties can be bred. Landraces or farmers' varieties serve as the foundation for the generation of any novel, improved varieties or hybrids. Landraces are crops that farmers have grown and cultivated over many years using a traditional selection technique (Elangovan et al., 2012).

Recent events have shown that the world's remaining plant genetic resources must be conserved and used sustainably if the world's expanding population is to be fed. By 2050, the anticipated global population will be 9.8 billion, which will need a significant increase in food grain production from the current annual rate of about five billion tonnes. A wider spectrum of plant genetic variation will need to be utilized frequently to fulfil the world's escalating food needs. However, the state of genetic resources is rapidly declining (United Nations, 2017). Plant genetic diversity loss was previously predominantly driven by natural processes, primarily as a result of climate change, and it continues to occur, though at a very low rate. On the other hand, the activities of the dominant species in the globe are the main cause of the current acceleration in the loss of plant genetic diversity. The destruction of natural habitats and the diversity they support have all been severely impacted by war and civil instability, overgrazing, forest removal and burning, indiscriminate fertilizer and pesticide use, and land clearing. Sodhi and Erhlich (2010) claim that earth-dominating species have damaged, damaged, and contaminated the natural environment of the earth, which is necessary for maintaining life (2010).

Sorghum (*Sorghum bicolor* (L.) Moench), a native crop of Africa (Kimber, 2003), will continue to be a staple food for many rural populations, despite changing market demands and uses over time. This is particularly true in parts of South Africa that are vulnerable to drought, where this robust crop outperforms maize in respect of food security for households. Sorghum is one of the undervalued indigenous crops with characteristics that make them suitable for production in low input agricultural systems and in marginal production areas that characterize South Africa's rural landscape (Hadebe et al., 2017). Sorghum is grown commercially in South Africa by both small and large-scale farmers. It is also grown more common as foundation crops in the food and beverage industries (Wenzel et al., 2001; Taylor, 2003). Small-scale farmers commonly cultivate sorghum landraces in a number of provinces across the country. Smallholder farmers favoured landraces despite their limited production capacity because of their broad adaptability, resilience to biotic and abiotic stressors, adequate quality, and beneficial agronomic properties (DAFF, 2010).

The South African National Plant Genetic Resources Centre (NPGRC), also known as the National gene bank, was established in 1995 as the national custodian to collect, manage, conserve, and promote the sustainable usage of Plant Genetic Resources for Food and Agriculture (PGRFA). The NPGRC is in charge of attaining national genetic material for PGRFA for long-term conservation and sustainable use. Between 1996 and 2008, the initial major effort on the collection and conservation of sorghum genetic variability was undertaken, with a total of 312 collections assembled. The National gene bank currently houses more than 6 275 ex situ collection accessions with passport data, and sorghum landraces accounts for 5% of the collections.

The systematic preservation of the genetic variability for the benefit of the present and the future is termed as conservation of plant genetic resource`s. Human exploitation of genetic variety is referred to as use. Collecting and preserving adaptable genetic variants for use in the future is the objective of conservation (Hammer and Teklu, 2008). Conservation and use of genetic resources are as old as agricultural civilization. For more than 12,000 years, farmers have been gathering seeds for future planting, harnessing wild plants, and choosing and breeding varieties to match their specific requirements and environments. Breeders can obtain the materials they require to develop novel varieties, and farmers can modify their crops in the face of changing climatic conditions and markets, thanks to the conservation of genetic resources. The two primary conservation techniques are in situ and ex situ conservation, and both use a range of approaches. The most typical results of conservation programmes include preserved germplasm, live and dried plants, cultures, and conservation data. To ensure safety, conservation items should be replicated in numerous places (Hammer and Teklu, 2008).

The availability of data, like with other aspects of biodiversity (Balmford et al., 2005), is crucial in order to thoroughly investigate these gains in agricultural biological variability. Empirical evidence is required to support or reject the widely held belief that crop diversity has been steadily decreasing over the past centuries. Despite the need for global indicators to raise public and policymakers' awareness of the state of the planet's biodiversity, it is clear that the trajectories and magnitude of biodiversity change vary depending on agronomic, cultural, and economic conditions. Several studies on varietal erosion have concentrated on small spatial or temporal scales. Morin et al., (2002) revealed, for example, that traditional rice cultivars were rapidly depleted following climatic disasters in the northern Philippines' Cagayan Valley. A diachronic (1979-2003) study of Asian rice molecular genetic variability in six Maritime Guinea villages found no evidence of genetic deterioration on an comparable geographical scale over a longer time period (Barry et al., 2008). Mekbib (2008) made the same discovery while researching the sorghum landrace names in eastern Ethiopia. Few attempts were made in documenting the collection and conservation of the sorghum landraces across the world. For instance, landrace collections in India have been reported to have a high degree of variation because the crop has been cultivated traditionally under varying agroclimatic conditions for centuries and has adapted to the environmental conditions (Elangovan et al., 2009; Elangovan et al., 2012). Sejake et al. (2020) indicated that the South African Agricultural Research Council houses more than 4000 sorghum accessions collected across the globe, including South Africa. Although few studies in relation to collection and geographic distribution of landraces were conducted across the globe, exploring the distribution of sorghum landrace collections from the South African national gene bank was never done. Therefore, the objectives of the study were to map and quantify the geographic distribution of collected and conserved sorghum (*Sorghum bicolor* (L) Moench) landraces in the South African gene bank from 1996 to 2008.

Materials and Methods

Data collection and sampling strategy

The study focused on the sorghum data captured in the collection database from the National Plant Genetic Resources Centre (NPGRC), also known as the National gene bank, following the collection mission of plant genetic resources (PGR) or landraces across the country, South Africa, for a period of 12 years (from 1996 to 2008). Some of the passport data that was utilized in this study included the coordinates, province, districts and municipalities, which were extracted from the collection forms. These PGR or landrace materials are currently being preserved for future use in the South African National Gene Bank. A total of 312 sorghum accessions were collected from six (6) provinces (Limpopo, Mpumalanga, North West, Free State, Eastern Cape and Kwa-Zulu Natal Provinces) wherein

152 villages located in 57 local municipalities, situated in 23 District Municipalities were explored during 1996 to 2008 (Figure 1; Table 1).

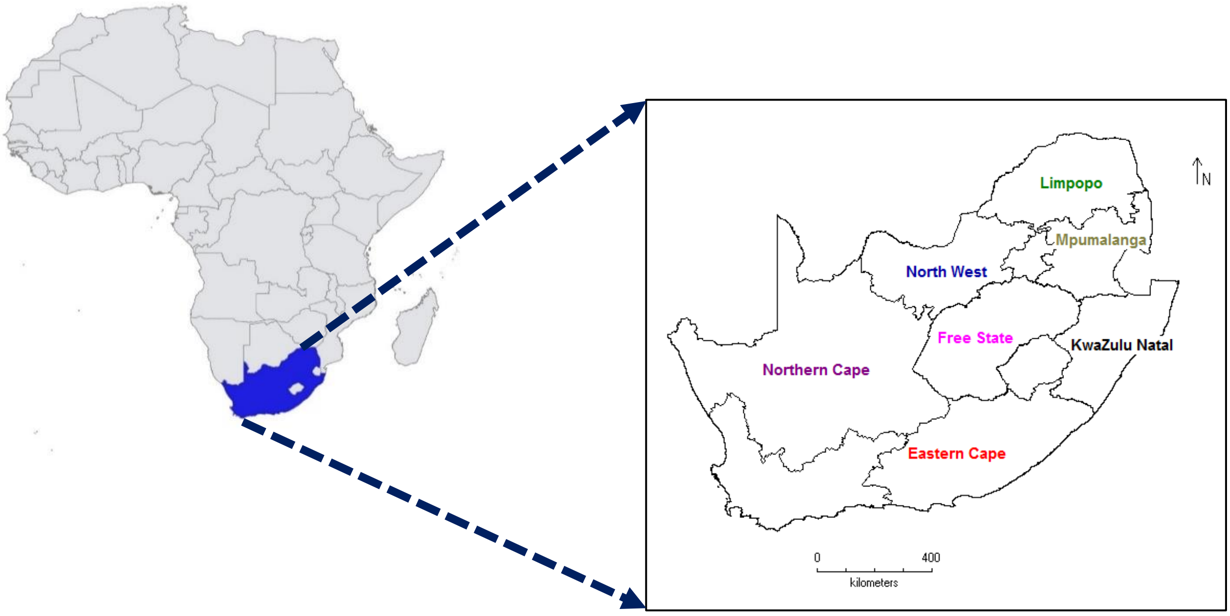

Figure 1: Map of the Republic of South Africa showing provinces where collections of sorghum landraces occurred. Source: QGIS.

Table 1 Collected sorghum (Sorghum bicolor (L.) Moench) landrace accessions per locality from 1996 to 2008.

Locality	Number of sorghum accessions
Provinces	6
Districts	23
Local Municipalities	57
Villages	152

Data analysis

The QGIS software was used to map the geographic distribution of sorghum accessions in the germplasm collections of the South African National gene bank. Coordinates from the collection sites were used to plot and generate the distribution map. The analysis of the data gathered from the study was done using the Statistical Package for the Social Sciences (SPSS) version 20 with the goal to quantify the distribution. Additionally, descriptive statistics comprising of the frequency, percentages, bar graphs, and frequency tables were performed.

Results and Discussion

Geographic distribution and collection of Sorghum landraces

The locations of the collection sites of one or several accessions of sorghum landraces are represented by a point on the geographic distribution map (Figure 2). The map reveals that Limpopo, KwaZulu Natal, and Mpumalanga Provinces hold the majority of the collected sorghum accessions. A relative uniform distribution of sorghum was observed in the Eastern Cape and North West Provinces, with the Free State Province showing the least distribution. Geographic diversity is widely associated with genetic diversity, but the latter is not always directly related to geographical distribution (Ganesamuthy et al., 2010; Elangovan et al., 2012).

The data on the number of sorghum accessions collected throughout South Africa from 1996 to 2008 is presented in Table 2. The sorghum collections ranged from 3.5% to 40.1% accessions from the Free State and Limpopo Provinces, respectively, for a period of 12 years. DAFF (2010) reported that majority of smallholder farmers estimated to produce more than 20 000 tons of sorghum in South Africa are from Limpopo province. This supports the findings that more than 40% of the collected and conserved sorghum landraces in the gene bank were from the Limpopo province. The collected sorghum accessions from KwaZulu Natal, Mpumalanga, Eastern Cape and North West recorded 18.1%, 16.7%, 10.9% and 10.6%, respectively.

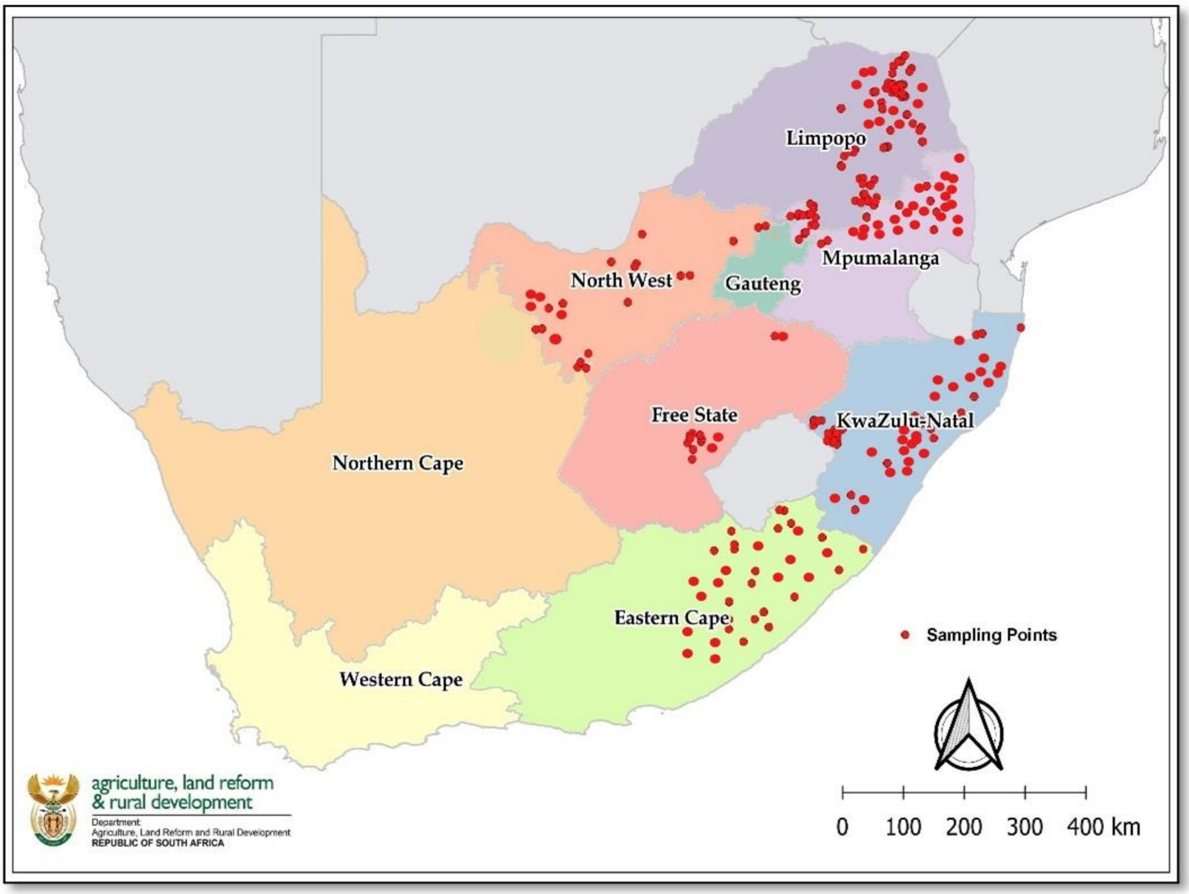

Figure 2 Geographic distribution of sorghum (Sorghum bicolor (L.) Moench) accessions across South Africa from 1996 to 2008. The points on the map indicate the sampling points of the collected sorghum accessions. Source: QGIS

Table 2 Quantifying sorghum (Sorghum bicolor (L.) Moench) landrace collections per province for a period of 12 years (1996 to 2008) in South Africa.

Provinces	Number of accessions (n)	Percentage (%)
Eastern Cape	34	10.9
Free State	11	3.5
KwaZulu Natal	57	18.3
Limpopo	125	40.1
Mpumalanga	52	16.7
North West	33	10.6
Total	312	100.0

Quantifying the collection of sorghum landraces from 1996 to 2008 per provinces

Sorghum (*Sorghum bicolor* (L.) Moench) is a significant food plant for small-scale farmers in semiarid regions of the world, providing sustenance for roughly 500 million of the world's poorest people (Reddy and Patil, 2015). The sorghum landraces conserved in the South African National gene bank in the first three years (1996, 1999 and 2001) dominated in the Limpopo province, with the maximum collection made in 2001 (Figure 3). According to DAFF (2010), smallholder farmers from the Limpopo province are growing sorghum on at least 25 342 ha and the production was more than 20 000 tons. DAFF (2010) reported further that the Free State, Mpumalanga, North West, Limpopo, and Gauteng provinces produce the most sorghum on a commercial scale, but Limpopo province produces the most on a small scale. The decreasing trend of sorghum collections was observed in the Limpopo and Eastern Cape provinces over the years (Figure 3). The collection mission for sorghum was expanded to the provinces of KwaZulu Natal and the Eastern Cape in 2002, with the majority of the sorghum collected in that year coming from the Eastern Cape province. In trying to expand the exploration of sorghum in the country, the collection mission was further extended to other provinces in 2003 (Figure 3). The collection of sorghum from the Free State province was only explored in 2004. The North West province was first investigated in 1996, when one (1) accession was gathered. Subsequent investigations took place over the following four years, in 2005, 2006, 2007, and 2008, yielding 15, 8, 6, and 3 accession collections, respectively. The substitution of traditional varieties with modern, high yielding, and genetically homogeneous varieties may contribute for the declining trend in sorghum collections over time (Girma, 2017). Ogwu et al., (2013) reported on the decline of traditional conservation practices as well as other customs. Figure 3 further shows that the collections in North West increased by 1.4% between 1996 to 2005 then started to decrease with years of exploration between 2005 and 2008.

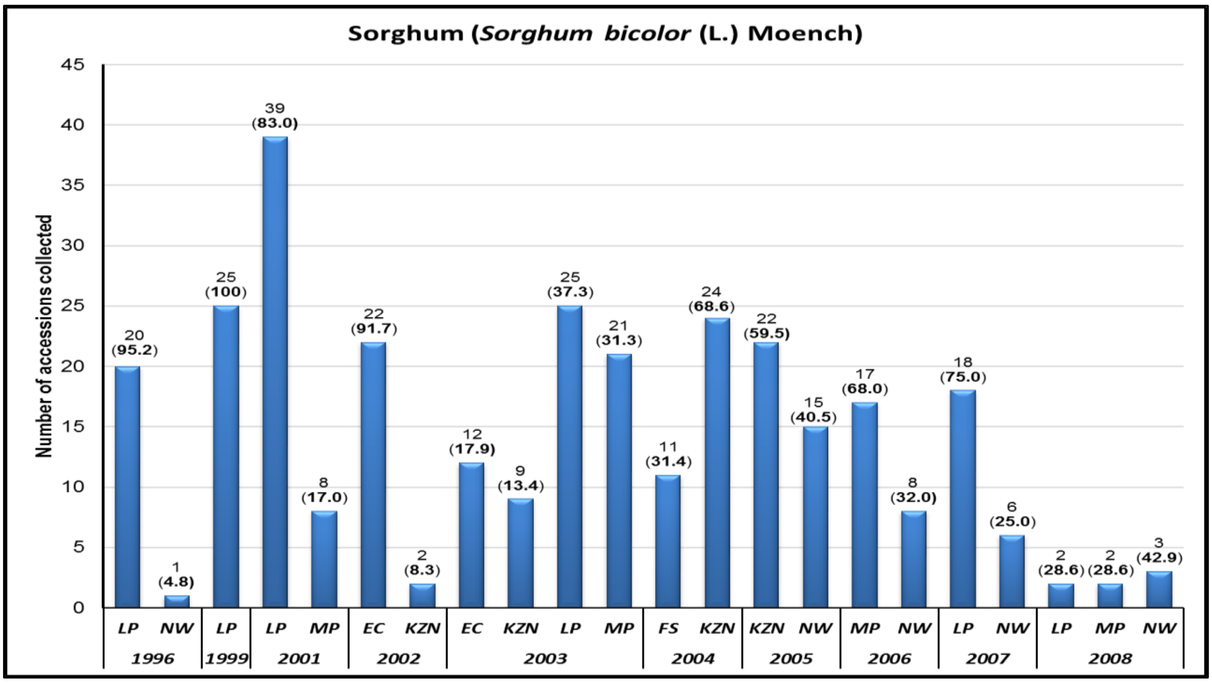

Figure 3 Collection distribution of sorghum (Sorghum bicolor (L.) Moench) accessions per provinces per year (from 1996 to 2008). The values on the bar indicates the frequencies and values in the brackets (…) indicates the percentages (%) of the collected material within a province per year. LP=Limpopo Province; NW=North West Province; MP= Mpumalanga Province; EC= Eastern Cape Province; KZN= KwaZulu Natal Province; FS= Free State Province.

Trend analysis on the collection of Sorghum landraces from 1996 to 2008

Figure 4 depicts the collection trends of sorghum accessions from 1996 to 2008 across the six explored provinces in South Africa. The collection of sorghum revealed an increasing trend from 1996, recording 6.7%, to 2003, recording 21.5%. Sorghum collection increased by more than three (3) times the initial collection made in 1996. This increase between 1996 to 2003 could have been due to the fact that more landraces were targeted for ex situ conservation (mass collection of landraces) and that had triggered the collection mission of those targeted landraces, including sorghum. FAO (2010) reported that between 1996 and 2008, the collection and preservation of plant genetic resources conserved in Ethiopia, China, and Kenya gene banks significantly increased by 46%, 9%, and 137%, respectively, which partly concurs with our findings. In contrast, there was a relatively consistent decrease in the collection of sorghum accessions observed from 2003 to 2008, which was more than 89%. The observed decrease could be attributed to farmers gradually shifting away from cultivating landraces in favor of improved varieties (Girma, 2017) or due to climate change related challenges (Afful, 2016).

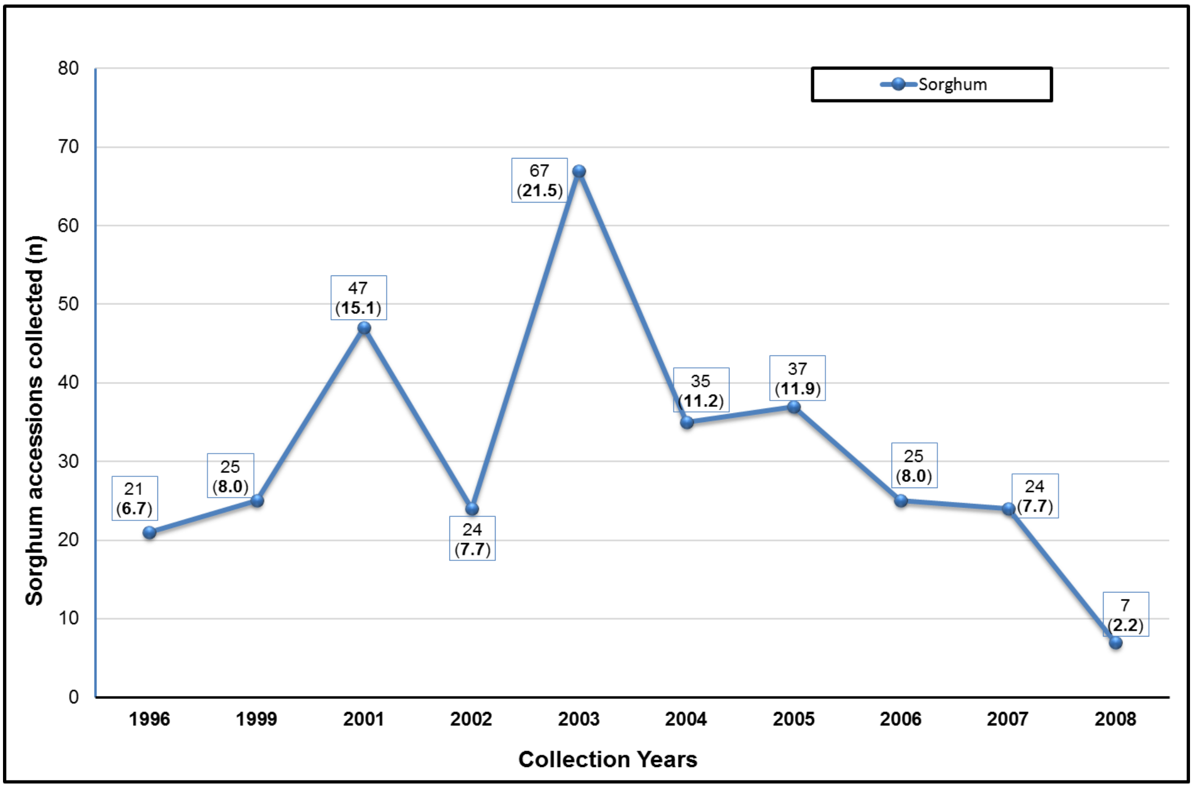

Figure 4 Trend analysis for Sorghum accessions collected and conserved in the South African National gene bank between 1996 to 2008. The values on the graph outside the brackets indicate the frequencies and the values within the brackets (..) indicate the percentages (%) of the collected material in that particular year.

Quantifying the collected and conserved sorghum landraces per district

Table 3 below shows the quantified sorghum landraces within the districts per specific provinces in South Africa. In the Eastern Cape province wherein 10.9% of the total sorghum collection in the gene bank came from, five districts were explored. Of the 10.9% sorghum collections from the Eastern Cape province, the maximum (32.4%) accessions were collected from Chris Hani district followed by Alfred Nzo (20.6%). The accessions collected from O.R Tambo district in the Eastern Cape province was the least (5.9%). In the Free State province, Motheo district was the only district explored. KwaZulu Natal was the only province with most explored districts. The collections from KwaZulu Natal contributed 18.3% of the total sorghum collections in the gene bank and the most collections were from uThukela district (42.1%) followed by uMkhanyakude district (22.8%). The Limpopo province collections contributed 40.1% from the total collections in the gene bank. Of this 40.1%, the maximum (45.7%) sorghum collections were from the Vhembe district. Two districts, Ehlanzeni and Nkangala, in the Mpumalanga province were explored wherein each district explored contributed 50% of the 16.7% from the Mpumalanga province. John Taolo Gaetsewe district in the North West province contributed 33.3% as the maximum, followed by Ngaka Modiri Molema district with 30.3%.

Table 3 Quantified Sorghum (Sorghum bicolor (L.) Moench) landraces collection within the districts from 1996 to 2008.

Provinces	Districts	Sorghum collection Frequency (n)	Percentage (%)
Eastern Cape	Alfred Nzo	7	20.6
	Amathole	5	14.7
	Chris Hani	11	32.4
	Joe Gqabi	9	26.5
	O.R.Tambo	2	5.9
Free State	Motheo	11	100.0
KwaZulu Natal	eThekwini Metropolitan	3	5.3
	Harry Gwala	3	5.3
	King Cetshwayo	12	21.1
	uMgungundlovu	1	1.8
	uMkhanyakude	13	22.8
	uThukela	24	42.1
	Zululand	1	1.8
Limpopo	Capricorn	25	19.7
	Mopani	22	17.3
	Sekhukhune	22	17.3
	Vhembe	58	45.7
Mpumalanga	Ehlanzeni	25	50.0
	Nkangala	25	50.0
North West	Bojanala Platinum	4	12.1
	John Taolo Gaetsewe	11	33.3
	Ngaka Modiri Molema	10	30.3
	Dr Ruth Segomotsi Mompati	8	24.2

Conclusion

The preservation of crop diversity is influenced by human desires and behaviours, and it may be necessary for adaptation to various future climate scenarios. Sorghum germplasm collections in South Africa represents greater genetic diversity because it is being historically cultivated under a range of different agro-climatic conditions. Changes in the geographical distribution of sorghum germplasms were seen between the 1996 and 2008 collections in South Africa, which could be explained by changes in environmental and agronomic conditions, the emergence of novel cultivars, and/or the establishment of innovative farming techniques. This underpins the need for an urgent attention to continue to collect and conserve the landraces for future use in the face of changing climate. Rotational collection from one province to the next and from one district to the next might also have influenced the current distribution. Sorghum germplasm collections in South Africa showed an important dispersion, covering different geographic areas, with the majority of collections made in Limpopo Province. The need for long-term monitoring on the landrace distribution is apparent. it is recommended that the unexplored parts of the country be thoroughly examined in order to gather highly crucial native landraces for conservation and sustainable usage. It is further recommended that the explored areas be revisited to determine the genetic erosion of the local landraces.

Acknowledgement

The author would like to acknowledge the Directorate Genetic Resources of the Department of Agriculture, Land Reform and Rural Development for funding the project and the attendance at the AGRICO 2022 Conference. The NPGRC team is also recognized for the technical support provided.

Declaration of Interest Statement

The author declares that he has no conflict of interest.

References

Afful, D.B. (2016). Public extension agents' need for new competencies: Evidence from climate variability study in Limpopo Province, South Africa. *South African Journal of Agricultural Extension*, 44(2), 59–70. http://dx.doi.org/10.17159/2413-3221/2016/v44n2a387.

Balmford, A., Crane, P., Dobson, A., Green, R.E., & Mace, G.M. (2005). The 2010 challenge: data availability, information needs and extraterrestrial insights. *Philosophical Transactions of The Royal Society B Biological Sciences*, 360 (1454), 221–228. https://doi.org/10.1098/rstb.2004.1599.

Barry, M.B., Pham, J.L., Be´avogui, S., Ghesquie`re, A., & Ahmadi, N. (2008). Diachronic (1979–2003) analysis of rice genetic diversity in Guinea did not reveal genetic erosion. *Genetic Resources and Crop Evolution*, 55, 723–733. https://doi.org/10.1007/s10722-007-9280-z

Department of Agriculture, Forestry and Fisheries (DAFF). (2010). Sorghum production guidelines. Pretoria. https://www.nda.agric.za/docs/brochures/prodguidesorghum.pdf (Accessed on 20 March 2022).

Elangovan, M., Ganesamurthy, K., Rajaram, S., Sankarapandian, K., & Kiranbabu, P. (2012). Collection and conservation of sorghum landraces from Tamil Nadu. *Electronic Journal of Plant Breed*, 3, 753–762.

Elangovan, M., Prabhakar, Tonapi V.A., & Reddy, C.S. (2009). Collection and characterization of Indian sorghum landraces. *Indian Journal of Plant Genetic Resources*, 22 (3), 173-181.

Food and Agriculture Organization of the United Nations (FAO). (2010). The Second Report on the State of the World's Plant Genetic Resources for Food and Agriculture. Rome.

Ganesamurthy, K., Punitha, D., & Elangovan, M. (2010). Genetic diversity among the local landraces collected in Tamil Nadu. *Electronic Journal of Plant Breeding*, 1 (6), 1375-1379.

Hadebe, S.T., Modi, A.T., & Mabhaudhi, T. (2017). Drought tolerance and water use of cereal crops: a focus on sorghum as a food security crop in Sub-Saharan Africa. *Journal of Agronomy and Crop Science*, 203, 177–191. https://doi.org/10.1111/jac.12191

Hammer, K., & Teklu, Y. (2008). Plant Genetic Resources: Selected issues from genetic erosion to genetic engineering. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*. 109 (1), 15 – 50

Kimber, C.T. (2003). Origin of domesticated sorghum and its early diffusion to India and China. pp. 3-98. In: Smith, C.W., & Frederiksen, R.A. Sorghum Origin, History, Technology and Production, (John Wiley and Sons, Inc., New York.

Mekbib, F. (2008). Genetic erosion of sorghum (Sorghum bicolor (L.) Moench) in the centre of diversity, Ethiopia. *Genetic Resources and Crop Evolution*, 55, 351–364. https://doi.org/10.1007/s10722-007-9240-7.

Morin, S.R., Calibo, M., Garcia-Belen, M., Pham, J.L., & Palis, F. (2002). Natural hazards and genetic diversity in rice. *Agriculture and Human Values*, 19 (2), 133–149. https://doi.org/10.1023/A:1016018711315.

Ogwu, M.C., Osawaru, M.E., & Ahana, C.M. (2014). Challenges in conserving and utilizing plant genetic resources (PGR). *International Journal of Genetics and Molecular Biology*. 6(2), 16-22. https://doi.org/10.5897/IJGMB2013.0083

Reddy, S., & Patil, J. (2015). Genetic Enhancement of Rabi Sorghum: Adapting the Indian durras. Academic Press, USA.

Girma, E. (2017). Genetic erosion of wheat (Triticum spp.): Concept, Research Results and challenges. *Journal of Natural Science Research*, 7(23). 72 – 81.

Sejake, T., Shargie, N., Christian, R., & Tsilo, T. (2020). Assessment of genetic diversity in sorghum germplasm using agro-morphological traits. South African Journal of Plant and Soil, 37 (5), 376 – 388. https://doi.org/10.1080/02571862.2020.1807628

Sodhi, N.S., & Erlich, P.R. (2010). Introduction. In: Conservation Biology for all. Sodhi, N.S., & Erhlich, P.R. (eds). Oxford University Press. p. 1.

Taylor, J.R.N. (2003). Overview: importance of sorghum in Africa. In: Belton, P.S., Taylor, J.R.N. (eds), Proceedings of the AFRIPRO workshop on the proteins of sorghums and millets: enhancing nutritional and functional properties for Africa, 2–4 April 2003, Pretoria, South Africa. Paper 01.

Ulukan, H. (2011). Plant genetic resources and breeding: current scenario and future prospects. *International Journal of Agriculture and Biology*, 13, 447-454.

United Nations. (2017). World population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100, 21 June 2017, New York. https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html (Accessed on 26 March 2022).

Wenzel, W.G., van Loggerenberg, M., & Ordon, F. (2001). Quick screening methods for sorghum quality traits. *Journal of Applied Botany*, 73, 43–45.