

Strengthening farmer-managed seed systems in South Africa

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Department: Agriculture, Land Reform and Rural Development
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Cover photos:
Left: Inspecting sorghum at the Jericho experimental field. Credit: Bioversity International/R. Vernooy
Top-right: Evaluating the yield of the participatory variety selection experiment (cowpea) in Gumbu, Limpopo. Credit: DALRRD-NPGRC/R. P. Sema
Bottom-right: Experimental field at Mbobo, Sterkspruit. Credit: DALRRD-NPGRC/L.A. Matelele.

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Credit: Bioversity International/R.Vernooy

Contents

1 INTRODUCTION

Credit: Bioversity International/R.Vernooy

Background

Farmers in South Africa have traditionally maintained local crop diversity (including major and minor crops, and in some areas fodder crops, forages and trees) using indigenous or local knowledge passed on through generations. Farmers select, plant, harvest, clean and store seeds of diverse crops with the aim of feeding their families, today and in the future. In many communities in the country, women play key roles as seed custodians and managers. In the village of Gumbu, Limpopo province, one of the sites of our activities, women lead agricultural activities and the efforts to conserve crop diversity in their community seed bank. However, traditional farmer seed conservation and management practices are being eroded as a result of increased commercialization of agriculture (with modern varieties and hybrids replacing traditional ones), and, in many areas, urban migration of the younger generation. Furthermore, heat waves and droughts are a threat to crop yields, and increase the threat of poverty, in particular in marginal areas where farming is so important to many smallholders, such as in Gumbu. Due to prolonged periods of drought, many households have lost their stocks of traditional seeds. Once lost, it is not easy to recuperate them as farmers everywhere face the same problems.

Overall, smallholder seed and food production systems in South Africa are threatened in the face of growing food demand, global warming and climate change, declining land and water resources, pests and disease, and environmental degradation. To counter this negative trend, there is a need to conserve and sustainably use plant genetic diversity, with a focus on traditional or farmer varieties. Since the inception of our collaborative activities in the country in 2013, we have strived to strengthen farmer-managed seed conservation and management practices, complemented more recently by farmer-centred crop improvement efforts in collaboration with the Agricultural Research Council - Vegetable, Industrial and Medicinal Plants (ARC-VIMP; formerly ARC-VOPI) campus at Roodeplaat (Gauteng), and the ARC-Grain Crops (ARC-GC) campus at Potchefstroom (North West Province), South Africa.

In South Africa, the management of crop diversity at farm level, of which community seed banking is an example, has been recognised as an effective method of conservation, particularly for traditional crop varieties (DALRRD 2017). Community seed banks have been at the centre of our work since 2013 as a means to encourage smallholder farmers to join forces, share seeds and related knowledge, and collaborate with other seed sector stakeholders, such as the National gene bank of South Africa, agricultural departments, plant breeders and other agricultural/rural development scientists and practitioners.

Community seed banks: local institutions for conservation and sustainable use of plant genetic resources

Establishing community seed banks allows farming communities to safely store farmers' own seeds. Community seed banks first emerged with a focus on conservation of crop diversity, but in recent years, some have developed additional and complementary activities, such as crop improvement and seed production and distribution (Vernooy et al. 2014; 2017). Emerging experiences suggest that community seed banks can deal with some of the major bottlenecks that many seed systems are facing. Seed production and distribution are not easy to venture into but appear to have good prospects as several examples demonstrate (Vernooy et al. 2022). Community seed banks also can function as an emergency seed supply when farmers experience a shortage of seeds due to crop failure due to floods, droughts or destruction of crops by pests and diseases. Moreover, they can serve as a channel to restore "lost" varieties in the community, for example, with the support of the national gene bank, which may still have seed of these varieties in its collection.

Community seed banks are platforms that can ensure effective implementation of farmers' rights. They can grow into centres for experimentation and innovation around seeds to secure their rights and interests in production in ways that are affordable, productive and respectful of the integrity of their landscapes and plant genetic resources. The conservation of the landraces in the form of seed banks is to maintain the integrity of the material conserved to the highest standard over prolonged periods of time (Upadhyaya et al. 2008).

To date, the Department of Agriculture, Land Reform and Rural Development (DALRRD; formerly the Department of Agriculture, Forestry and Fisheries or DAFF), in collaboration with Bioversity International (now part of the Alliance of Bioversity International and CIAT), has established three community seed banks in the country, one in Limpopo (Gumbu, Photo 1), one in Eastern Cape (Mbobo village, not far from Sterkspruit, Joe Nqabi district municipality) and one in North West province (Jericho) (Matelele et al. 2018). The aim is to scale these out in the coming years and set up several more, eventually forming a network of community seed banks in the country.

In Sterkspruit, farmers use a temporary facility in the town to store seed, established on land of the district

Photo 1: At the Gumbu community seed bank. Credit: Bioversity International/R. Vernooy

farmers' association; in the near future, the collection will likely be moved to Mbobo village. In Gumbu, farmers store their seed in a solid and spacious newly built structure, which has a convenient meeting area donated by the village headman, officially inaugurated in March 2016. The facility has a large area of land, where crops can be grown (i.e., seeds multiplied) and experiments carried out. In Jericho, farmers are using an existing structure donated by the Tribal Authority, which was renovated and inaugurated in June 2019. The Jericho facility also includes an area to cultivate (i.e., to multiply seed) by the members of the community seed bank. Chapter 2 presents the results of the most recent community seed banking activities in the three sites.

In all three sites, farmers are facing the impact of climate change, manifested in changes in temperatures (day, night, seasonal averages), levels, durations and intensities of precipitation, and (shifting) starting dates of the rainy seasons. Annex 1 presents climate data (2006-2020) of the three sites in more detail.

Piloting community seed banks in South Africa

Following an in-depth community assessment of trends in agricultural biodiversity conservation and use, carried out in 2013 in two selected smallholder farming areas, the process of establishing a community seed bank was initiated through a number of capacity development activities related to technical and organizational aspects of running a community seed bank (Vernooy et al. 2013), such as seed selection and conservation, storage techniques, and seed registration (Gómez César et al. 2016). The first two pilot sites were Gumbu village in Mutale municipality in Limpopo province and Sterkspruit town of Joe Nqcabi district municipality in Eastern Cape Province (Maluleke et al. 2014; Tjikana et al. 2016). Later, in 2017-2018, the pilot experiences were used to establish a new community seed bank in Jericho of North West Province. In the start-up period, farmers focused their activities on building up the first collection of seeds for the community seed banks through activities such as seed and food fairs, creating awareness about the importance of conservation of indigenous/local crop diversity and learning how to collectively set up a community seed bank (Vernooy et al. 2016).

In 2018-2019, farmers of the three community seed banks started to multiply seed of selected crop varieties stored in the three community seed banks; e.g. the Gumbu farmers planted 13 crops. Farmers prioritized the type of crops they wanted to multiply based on the quantities available in the community seed banks and their crop preferences. Not all went as planned though, due to drought that hit the country and an outbreak of army worms in Gumbu (Matelele et al. 2018).

One of the highlights of 2019 was the celebration of local crop diversity through the organization of a food fair in Jericho, where farmers from Gumbu and Jericho displayed traditional seeds and food dishes prepared from the crop diversity available in their community seed banks. The traditional food/seed fair is an activity that the project team and the Provincial Departments of Agriculture from Limpopo and Eastern Cape have implemented since 2013. Such fairs raise awareness about the importance of using and conserving local crop diversity and create opportunities for active exchange of food recipes, seeds and related knowledge. The purpose of this food/seed fair was for Gumbu and Jericho farmers to share their experience and knowledge about community seed banking with farmers from two other Provinces — Free State and Northern Cape, which have been identified for the establishment of new community seed banks — as well as other farmers from neighbouring communities who attended the event (Photo 2). Farmers from Gumbu and Jericho prepared different types of traditional food for display and tasting. The Gumbu farmers also displayed seeds from Limpopo, which they donated to the Jericho community seed bank at the end of the event.

Photo 2: Farmers exchange seed at the Jericho food and seed fair.
Credit: Bioversity International/R. Vernooy

During the fair, the attendees were given a chance to view, ask information and taste the food prepared by the farmers. Participating farmers explained how they had prepared their food and which seeds were used (Mokoena et al. 2019).

A second highlight was a study tour to neighbouring Zimbabwe, a pioneer in community seed banking through the research and development activities of the Community Technology Development Trust (CTDT), recently renamed the Community Technology Development Organisation (CTDO). CTDT collaborates closely with national and international organizations operating in Zimbabwe. CTDT has developed a unique approach to community seed banking through the Farmer Field School (FFS) approach and by complementing conservation of agrobiodiversity with participatory crop improvement and farmer seed production and distribution.

The study tour took place from 25 to 29 March 2019. The mission was aimed at obtaining a better understanding of how to build effective linkages between farmers, the National Genebank, research institutions, the extension service (and other stakeholders) towards successful community seed banking at national level.

Activities carried out during the visit included: (i) meetings and discussions with CTDT staff about the work in South Africa and Zimbabwe and the prospects of future collaboration; (ii) a meeting with staff of the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement; (iii) a visit to the National Genebank of Zimbabwe; (iv) meetings with the Ambassador Extraordinary and Plenipotentiary of the Republic of South Africa in Zimbabwe, His Excellency Mr. M.N. Mbete; and (v) various field visits within Mudzi and Uzumba-Maramba Pfungwe districts. The field trips allowed the DAFF and Bioversity International team to learn about the operations of the community seed banks, take part in seed fairs, observe the Farmer Field Schools' participatory crop improvement efforts, and discuss the farmer seed production and distribution activities (for a detailed brief about the visit, see Vernooy et al. 2019).

Covid-19 and renewed activities

The period 2019-2021 was challenging for the farmers and the support team due to the global outbreak of Covid-19. Traveling to South Africa and to the sites was suspended for a long time and difficult for another period; while the farmers faced multiple hardships to produce food for their families and maintain the community seed banks operational. Notwithstanding the difficult situation, the new activity of participatory variety selection (PVS) was initiated to complement the conservation activities. During December 2020, the project team of ARC and DALRRD travelled to the three community seed banks and obtained five sorghum and six pearl millet landraces as contributions from the participating farmers for the PVS trials. The National Plant Genetic Resources Centre added nine sorghum accessions from the gene bank; and the Agricultural Research Council (ARC) added one sorghum and four pearl millet lines/open pollinated varieties as check varieties. In 2021 and 2022, follow-up visits were made to monitor and eventually, evaluate the PVS trials together with the farmers. The crops of the replication trials at the ARC research stations in Loskop (Photo 3) and Potchefstroom were harvested and some data analysis was carried out. Details will be presented in Chapter 3.

Photo 3: Preparing the trials at the Loskop station. Credit: DALLRD-NPGRC/L.A. Matelele

2 RECENT COMMUNITY SEED BANKING ACTIVITIES (2021-2022)

Credit: Bioversity International/R.Vernooy

During 2021 and 2022, Department of Agriculture, Land Reform and Rural Development officials monitored activities of the three community seed banks in Gumbu, Jericho and Sterkspruit, through the following activities: verification of the viability of the seeds in the community seed banks; checking the progress of crops that were planted during the previous season to increase seed quantities stored in the community seed banks; recording the harvests of the seed multiplication plots; assisting farmers to register their conserved seeds; conducting new planting of multiplication plots; conducting refresher training on conservation; and updating the community seed bank databases.

Gumbu

In Gumbu, the farmers planted cowpea, maize, melon, pumpkin, sorghum, sweet sorghum and watermelon, to increase the quantities of seed during the 2021/22 planting season (Photo 4). Harvesting was done from May to June 2022 and seeds were cleaned, dried, stored and registered in the community seed bank register with the assistance of DALRRD officials. For the 2022/23 planting season, the following crops were selected and planted in December 2022: Bambara nut, black-eyed bean, calabash, cowpea, finger millet, maize, mung bean, pearl millet (from the PVS experiment), pumpkin, sesame, sorghum, and watermelon. The collection has grown over the years and reached 246 donations of 15 crop and one tree species (Table 1). For comparison, on 31 December 2016, the collection included 165 donations of 13 crop species.

Photo 4: Seed multiplication at the Gumbu community seed bank. Credit: Bioversity International/R. Vernooy

Table 1. Crops conserved in the Gumbu community seed bank (31 December 2022)

Crop name	Local name	Variety name	# donations
Amaranth (*Amaranthus cruentus*)	Muroho	Wa vowa	1
Bambara groundnut – jugo bean (*Vigna subterranea*)	Phonda	Phonda	5
Calabash (*Lagenaria siceraria*)	Khabo	Khabo	17
Calabash (*Lagenaria siceraria*)	Tshitemba	Tshitemba	2
Cowpea (*Vigna unguiculata*)	Nawa	Luti	24
Cowpea (*Vigna unguiculata*) – black-eyed pea	Nawa	Mulomumotsho	4
Finger millet (*Eleusine coracana*)	Luvhele	Mufhoho	4
Groundnut (*Arachis hypogaea*)	Nduhu	Nduhu	11
Maize (*Zea mays*)	Tshikoli	Tshitshena	28
Maize (*Zea mays*)	Tshikoli	Tshitshuku	12
Maize (*Zea mays*)	Tshikoli	Tshitavatshindi	8
Moringa (*Moringa oleifera*)	Muringa	Muringa	2
Mung bean (*Vigna radiata*)	Thumbe	Thumbe	3
Okra (*Abelmoschus esculentus*)	Delele		10
Pearl millet (*Pennisetum glaucum*)	Luvhele	Luvhele-vhele	14
Pumpkin (*Cucurbita maxima*)	Mapfuri	Madzanga	32
Sorghum (*Sorghum bicolor*)	Makhaha	Lufshalane	25
Sorghum (*Sorghum bicolor*)	Makhaha	Lenthade (Tshikotame)	18
Sweet sorghum (*Sorghum bicolor*)	Nkhewe	Nkhewe	3
Tepary bean	Nawa	Tapara	11
Watermelon	Mabvani	Mabvani	10
Wheat	Korong	Korong	2
TOTAL			**246**

The Limpopo provincial Department of Agriculture has adopted the Farmer Field Schools (FFS) programme by teaching farmers new practical skills. Gumbu is one of the villages where the programme is implemented. The extension officers are now involved in training farmers to help ensure food security by teaching them how to farm and use good farming practices. Since the programme is new and still needs to be adopted by farmers, the extension officers are grouping farmers from Gumbu village including some of the community seed bank members. They work with calabash, okra, and sorghum (two of the PVS crops).

Jericho

In Jericho, in the same period, the farmers planted Bambara groundnut, cowpea, maize obtained from Gumbu, pearl millet obtained from Gumbu, pumpkin, sweet sorghum, and watermelon. The farmers managed to obtain a good harvest of all the crops. Harvesting of material planted during the 2021/22 season was done during April to May 2022 and the material was processed and registered in the community seed bank record book with the assistance of the DALRRD officials. For the 2022/23 season, farmers selected Bambara groundnut (white and black), groundnut, maize (white and yellow), pumpkin, and tepary bean; all species with small quantities available in the community seed bank. The collection of the Jericho community seed bank reached 119 donations of 16 crop species; six donations were removed due to infestation with weevils (Table 2).

Apart from using the land area of the community seed bank for multiplication purposes, farmers are also cultivating an area with vegetables (beetroot, kale, onion, spinach), as a means to generate income from local sales. The PVS experiment sparked interest to include okra in this activity.

Table 2. Crops conserved in the Jericho community seed bank (31 December 2022)

Crop name	Local name	# donations
Bean (*Phaseolus vulgaris*)	Dinawa	4
Calabash (*Lagenaria siceraria*)	Sego	15
Bambara groundnut - jugo bean (*Vigna subterranea*)	Ditloo	4
Cowpea (*Vigna unguiculata*)	Dinawa tsa setswana	8
Cowpea (*Vigna unguiculata*) – black-eyed pea	Dinawa tsa setswana	1
Groundnut (*Arachis hypogaea*)	Mato komane	1
Maize (*Zea mays*)	Mmidi	11
Melon (*Cucumis melo*)	Lerotse	7
Mung bean (*Vigna radiata*)	Lehlodi	1
Okra (*Abelmoschus esculentus*)	Thelele	10
Pearl millet (*Pennisetum glaucum*)	Leotsa	5
Pumpkin (*Cucurbita maxima*)	Lephutsi	12
Sorghum (*Sorghum bicolor*)	Mabelethero	23
Soybean (*Glycine max*)	Dinawa	1
Spider plant (*Cleome*)	Lerotho	2
Watermelon (*Citrullus lanatus*)	Legapu	13
Wild cucumber	Phare	1
TOTAL		**119**

Sterkspruit

In previous years, the Sterkspruit farmers used a small area of land in the town of Sterkspruit to multiply seed, but it proved to be too costly and time-consuming to continue this practice. Instead, in 2021, they obtained a piece of land from the traditional office in Mbobo village where they conducted multiplication of seed during the 2021/2022 planting season. The farmers planted beans, maize, pearl millet, pumpkin, and sorghum. Harvesting was done during July 2022. However, the area experienced too much rain from December 2021 until early March 2022. This affected the growth and yield of all the crop. Due to this challenge, only small quantities could be harvested.

For the 2022/23 season, farmers selected beans, cowpea, maize (red and yellow), and pumpkin. They agreed to take some seeds from the community seed bank collection and increase the amounts from their household seed collections. The landrace seed collection conserved in the Sterkspruit was observed to be in good state; however, it remains to be verified through a germination test and/or field testing to find out if all the seeds are still viable. The seeds in the Sterkspruit facility have been stored for some years now (Photo 5). From observation, it appears that the use of zeolite beads has had a positive effect, considering the dryness of the seeds stored in the bottles. Only one maize accession was found to have been infested by insects due to a lid that was not tightly closed; the seeds were discarded. 103 donations of 11 crop species were stored, of which 44 of maize (five varieties) (Table 3). For comparison, on 31 December 2016, there were 74 donations of 10 crops stored.

Photo 5: Sterkspruit community seed bank.
Credit: DALRRD-NPGRC/R.P. Sema

Table 3. Crops conserved in the Sterkspruit community seed bank (31 December 2022)

Crop name	Local name	Variety name	# donations
Bean (*Phaseolus vulgaris*)	Imbotyi	Imbotyi emhlophe	2
Bean (*Phaseolus vulgaris*)	Imbotyi	Imbotyi emdaka	1
Bean (*Phaseolus vulgaris*)	Imbotyi	Imbotyi yagwatsika	4
Calabash (*Lagenaria siceraria*)	Umcephe	Iselwa	1
Cowpea (*Vigna unguiculata*)	Nawa/inhlomaya	Nemnyama	1
Maize (*Zea mays*)	Umbona	Bosmaan	15
Maize (*Zea mays*)	Umbona	Galawe/matinyawe	4
Maize (*Zea mays*)	Umbona	Gazitjeketje	7
Maize (*Zea mays*)	Umbona	Gxhebehlungulu	4
Maize (*Zea mays*)	Umbona	Nyangantathu	11
Maize (*Zea mays*)	Umbona	Maplanka	3
Okra (*Abelmoschus esculentus*)	[not known]		10
Pea (*Pisum sativum*)	Eretyis	Eretyis	5
Pearl millet (*Pennisetum glaucum*)	[not known]		6
Pumpkin (*Cucurbita maxima*)	Ithanga/iphuzi	Solontsi	8
Sorghum (*Sorghum bicolor*)	Amazimba	Amazimba amhlophe	15
Sunflower (*Helianthus annuus*)	Nyakatya		1
Watermelon (*Citrullus lanatus*)	Ivatala	Ivatala	5
TOTAL			**103**

3 PARTICIPATORY CROP IMPROVEMENT

Credit: Bioversity International/R.Vernooy

Participatory roles of farmers in crop improvement

To strengthen the community seed banking activities of the farmers in the three sites and build a more resilient seed system, the team introduced the concept and practice of participatory crop improvement, which was well received. Participatory research drives community-led innovation, aimed at encouraging widespread technology adoption of economically viable and ecologically resilient sustainable agricultural production practices in rural small-scale farmers. Demand-driven participatory plant breeding is the process by which the end users, especially small-scale farmers, are closely and actively involved in participatory varietal selection. Demand-driven research is further characterised by paying attention to possible differences (in interests, points of view, preferred traits) based on social factors and gender. This provides an opportunity for farmers to make informed decisions for selection of demand-driven target products throughout the breeding cycle. It also helps farmers adapt technologies to local agro-ecologies, social and economic conditions using indigenous and common knowledge.

Demand-driven varietal selection from source genotypes based on the preference of farmers/ communities in plant breeding is a process where indigenous knowledge is shared by local farmers and indigenous people with scientists. This allows to develop appropriate links and systems that bond research and development objectives. It directly involves and links the end users in the crop improvement activities and seed supply systems. Based on discussions with the farmers in the three sites, it was decided to include four crops of interest in the PVS trials: cowpea, okra, pearl millet, and sorghum. Of these, the community seed banks maintain some seeds of cowpea, pearl millet and sorghum, but not of okra. These are underutilized crops in developing countries including South Africa for food, nutrition and health security. They contain high nutritional compositions such as carbohydrate, minerals, vitamins, proteins, and starch, making the crops very important sources of dietary needs in the food system. They also contribute to income generation. These crops are extremely tolerant to poor-quality soils and drought, as well as their ability to yield a crop in conditions where other crops fail, particularly suitable for the low-input agricultural production systems in the drought-prone regions.

Besides its use as food and forage, cowpea is an important crop to include in cropping systems as it can fix atmospheric nitrogen, thus replenish soil nitrogen. The crop can grow in low rainfall areas and improve the fertility of soils in marginal lands by providing ground cover and crop residues, fixing atmospheric nitrogen and suppressing weeds. Cowpea, thus, has the potential to be an ideal crop for production in drier regions in Africa, particularly in South Africa. The legume crops are suitable in intercropping systems with sorghum and pearl millet. The crops are also good sources of animal feed.

Okra is a multipurpose crop due to its various uses of pods, fresh leaves, buds, flowers, stems, roots, and seeds. The immature fruits of okra are consumed as vegetables in the form of salad, soups, and stews, fresh or dried, fried or boiled. This species is under-exploited and has the potential to contribute to food and nutritional security for the growing population, play a vital role in income generation and poverty alleviation. Okra provides dietary fibers and distinct seed protein balanced in both lysine and tryptophan amino acids.

Pearl millet and sorghum are two of the underutilized indigenous crops that possess attributes that make them ideal for production under low-input agricultural systems and in marginal production areas which typify South Africa's rural landscape. Sorghum and millet have been noted as staple food grains in many semi-arid and tropic areas of the world, particularly in sub-Saharan Africa, because of their good adaptation to hard environments and their good yield of production, but still under-researched compared to other cereals.

Community seed banks and the introduction of 'new crops' to broaden the food base

The selection of the four crops for the PVS activities served another important purpose, namely, to broaden the food basis of South Africa's population. All four crops have high nutritional values, but some of them have not been traditionally cultivated, notably okra, which in Eastern Cape and North-West Province is a relatively 'new' crop; in Gumbu, farmers have been cultivating okra for some years. Farmers in Sterkspruit and farmers and adjacent communities in Jericho were informed about the health benefits of eating okra in a country where sugar-related health problems and obesity are major challenges. The farmers expressed great interest in incorporating okra in their production systems. As a result, the ARC is receiving several requests for seed. Despite its modest advancement in agriculture and food production, the South African food system is characterised as narrow, providing very limited options other than the handful established (major) food crops. Sharing of seeds of the 'new' crops among through the community seed banks can contribute to broadening the food base and food system's resilience.

Photo 7: Sorghum trial at Potchefstroom.
Credit: Bioversity International/R. Vernooy

Results

Trials were conducted in the field in Gumbu, Jericho and Mbobo village, and at two ARC research stations, Loskop (Mpumalanga) and Potchefstroom (North-West province) (Photos 6 and 7).

Photo 6: Okra trial at Loskop.
Credit: Bioversity International/R. Vernooy

Sorghum

The land was tractor-ploughed and disked prior to field marking and planting took place in December 2021. Following disking the land, the team marked the field wherein a total of 14 sorghum accessions were planted, sourced from farmers' fields in Gumbu (four varieties), Jericho (one variety), and the PGRC (nine varieties). The design was a randomized complete block design (RCBD), with three replications. Each accession planted was represented in two rows. A spacing of 5 m long rows and 0.75 m between the rows was used. T-markers with the name of the plot were used to label the planted accessions and to demarcate the plots. The sorghum grew well in Gumbo and Jericho, but not in Mbobo, where all the trials were badly affected by heavy rains and the almost complete flooding of the site. Unfortunately, not much could be rescued despite tireless efforts by the farmers to drain the water from the field.

Table 4. Farmers participatory evaluation and selection of sorghum landraces/farmer varieties in Gumbu (N=15) and Jericho (N=25), 2021/2022

No.	Landrace / Accession designation	Seed source	Traits farmers used for the selection	Farmers' ranking	
				Gumbu	Jericho
1	NGM-3	CSB, Gumbu	Easy to dry, ratooning ability	1st	
2	NGM-4	CSB, Gumbu			
3	NGM-6	CSB, Gumbu			
4	NGM-7	CSB, Gumbu	Panicle type and size, staying green	2nd	
5	NML-1	CSB, Jericho	Taste, agronomic performance	4th	3rd
6	1455.1.1.1	NPGRC			
7	2055.2.1.1	NPGRC	Ratooning ability	3rd	
8	3262	NPGRC			
9	3281.1.1.1	NPGRC			
10	3301.1.1.1	NPGRC			
11	3319.1.1.1	NPGRC	High yield		2nd
12	4303.1.1.1	NPGRC	High yield	5th	1st
13	4312.1.1.1	NPGRC			
14	5462.1.1.1	NPGRC			

Photo 8: Evaluating the yield of the participatory variety selection experiment (sorghum), Jericho. Credit: Bioversity International/R. Vernooy

In March 2022, in Gumbu and Jericho (see the Jericho experimental plot on Photo 8), farmers evaluated the same 14 varieties of sorghum that were sourced from farmers' fields in Gumbu and Jericho (five varieties) and the PGRC (nine varieties). The scoring, which was based on consent among the two groups of farmers, are presented in Table 4, resulting in clear differences in selection order.

Pearl millet

The planted pearl millets were collected from the Gumbu (five) and Jericho community seed bank (CSB) (one), totalling six accessions. These accessions were planted in all three sites, in RCBD design with three replications. Each accession was planted in 5 m long row with 0.75 m between rows spacing. The distance between the blocks/replications was 1 m. The scoring, which was based on consent among the two groups of farmers, are presented in Table 5, showing almost no differences in selection order.

Table 5. Farmers participatory evaluation and selection of pearl millet landraces/farmer varieties at Gumbu (N=15) and Jericho (N=25) community seed bank sites, 2021/2022

No.	Landrace / Accession designation	Seed source	Traits farmers used for the selection	Farmers' ranking	
				Gumbu	Jericho
1	NGM-9	CSB, Gumbu	Drought tolerance, used for brewing, good taste	2nd	1st
2	NGM-10	CSB, Gumbu	Food quality, panicle size (yield)	3rd	3rd
3	NGM-11	CSB, Gumbu	Good tillering, panicle size	3rd	3rd
4	NGM-12	CSB, Gumbu			
5	NGM-13	CSB, Gumbu			
6	NML-2	CSB, Jericho	Panicle size (yield), green stalk	1st	2nd

Cowpea

The accessions of cowpea, all sourced from the PGRC, were planted in three different locations: at the ARC Loskop experimental farm, Gumbu, Jericho, and Mbobo village in November and December 2021. The fields were demarcated using T-markers. The experimental design used in all four sites to plant 10 cowpea accessions was a RCBD with three replications in Loskop experimental farm and Gumbu, and two in Jericho and Mbobo. This was due to shortage of cowpea seeds prepared for planting in that area. Each accession was planted in one row, with 1 m distance between plants and 1 m distance between rows. The distance between the replication plots was 1 m. Table 6 presents the results of farmers' scoring in Gumbu and Jericho. The scoring of the five best performing of the planted accessions, which was based on consent among the two groups of farmers, are presented in Table 6, resulting in some differences in selection order. Farmers did not evaluate the cowpea at the Mbono village site due to the impact of the flooding.

Table 6. Farmers participatory evaluation and selection of cowpea landraces/farmer varieties at the Gumbu (N=15) and Jericho (N=25) community seed bank sites, 2021/2022

Accession No.	Total seed weight (g)	Farmers' preference	Farmers' ranking	
			Gumbu	Jericho
1975.1.1.1	259.51	Early maturing type, tolerant to drought	3rd	3rd
2042.1.1.1	115.73	Green pods for salad, good pod setting	4th	4th
1958.1.1.1	136.72	Good vegetatively growth and good pod setting, dual use	1st	5th
2024.1.1.1	308.99	Bushy type, soft leaves for vegetable cowpea as salad	2nd	1st
2053.1.1.1	233.62	Leafy cowpea as vegetable, animal feed, early maturing	5th	2nd

Okra

Twenty-four okra accessions sourced from the PGRC were planted in four locations: Loskop experimental farm, Gumbu, Jericho, and Mbobo village in November and December (2021) and January (2022) (Photos 9 and 10). A randomised complete block design (RCBD), with three replications was used in Gumbu, two replications in Mbobo, and one replication in Jericho due to lack of land. Each accession was planted in two rows in both sites. The distance between rows and plants was 1 m and 0.50 m, respectively. 1 m distance was used to separate the replications. The accessions were randomised in each replication to allow the greatest reliability and validity of statistical estimates of treatment effects. The okra experiment was only evaluated in Jericho, but only five accessions were ranked; in Gumbu, no field data could be collected due to the poor state of the crop; in Mbobo village farmers ranked six of the planted accessions based on an assessment of the impact of the heavy flooding of the land due to heavy rains. The farmers' scoring in Jericho is presented in Table 7.

Despite the poor state of the okra in Mbobo village, farmers evaluated the surviving accessions. Table 8 presents their ranking.

Table 7. Farmers participatory evaluation and selection of okra landraces/farmer varieties at the Jericho community seed bank site (N=25), 2021/2022

Accession No.	Seed weight (g)	Farmers' preference	Farmers' ranking
1827.2.3.1	162.3	High number of pods	1st
1233.2.3.1	78.3		4th
1181.2.1.1	63.2	Good pod setting, high number of pods	3rd
1733.3.1.2	100.2	High number of pods	2nd
1856.2.3.1	101.3	Good pod setting, long pod, drought tolerance	5th

Table 8. Farmers participatory evaluation and selection of okra landraces/farmer varieties at Mbobo village, 2021/2022 (N=15)

Accession No.	Seed weight (g)	Farmers' ranking
4225.1.1.1	Resistance to water logging and produces some pods	1st
1806.2.3.1	Resistance to water logging	2nd
1900.2.3.1	Resistance to water logging	3rd
1214.3.1.2	Resistance to water logging	4th
1233.2.3.1	Resistance to water logging	5th
1622.2.3.1	Resistance to water logging	6th

Photo 9 and 10: Okra trial in Gumbu (left) and Jericho (right). Credit: Bioversity International and CIAT/R. Vernooy

Yield and yield performance of sorghum and pearl millet accessions

The yield data for both sorghum and pearl millet were collected from the accessions planted in Potchefstroom and Jericho. The yield data for Gumbu were not collected due to the damage that the birds caused in the field; netting was not done. The pearl millet and sorghum yielded in Potchefstroom and Jericho excellently, not affected by the birds, as the heads/panicles were covered on time with nets. In measuring yield for both grain crops, the heads/panicles were harvested and threshed. The seeds were weighed using a weighing balance. The quantity of grain produced per accession is presented in Table 9.

Table 9. Quantity of sorghum grain produced by each landrace/accession grown at Jericho and on Potchefstroom, 2021/22

No.	Accession Name	Grain quantity obtained (kg/7.5m²)	
		Potchefstroom	Jericho
1	NGM-3	1.41	4.35
2	NGM-4	0.7	1.94
3	NGM-6	1.32	2.25
4	NGM-7	0.84	2.36
5	NML-1	2.14	1.43
6	1455.1.1.1	2.84	*
7	2055.2.1.1	3.93	1.44
8	3262	2.47	*
9	3281.1.1.1	1.89	1.09
10	3301.1.1.1	1.94	1.01
11	3319.1.1.1	2.64	2.1
12	4303.1.1.1	3.36	1.91
13	4312.1.1.1	4.04	*
14	5462,1,1,1	1.74	*
	AVERAGE	2.23 (2,973kg/ha)	1.99 (2,653kg/ha)

Sorghum yield in Potchefstroom was recorded for all the planted accessions and ranged from 0.7 kg/ 7.5 m^2 (accession NGM-4) to 4.04 kg/7.5 m^2 (accession 4312.1.1.1). In Jericho, the yield data was recorded for 11 of the 14 planted accessions. The recorded yield data ranged from 1.01kg/7.5 m^2 (1346 kg/ha, accession 3301.1.1.1) to 4.35 kg/7.5 m^2 (5,800 kg/ha, NGM-3). Generally, the average yield performance of sorghum accessions planted in Potchefstroom (2.23 kg/7.5 m^2 or 2,973 kg/ha) was 11.4% higher than those planted at Jericho (1.99 kg/7.5 m^2 or 2,653 kg/ha). The difference in field and crop management employed in these two areas could have contributed to this yield variations. The variation in weather and soil factors could be contributing factors as well.

The yield performance of pearl millet planted in Jericho (Photo 11) was much better than those from Potchefstroom. The average yield across the accessions was 1.08 kg/7.5 m^2 (1,440 kg/ha) and 0.98 kg/7.5 m^2 (1,306 kg/ha) recorded for Jericho CSB and Potchefstroom, respectively. In Potchefstroom, the yield performance of planted pearl millet accession NGM-2 was the highest (1.2 kg/7.5 m^2 or 1,600 kg/ ha) followed by NGM-10 (1.1 kg/7.5 m^2 or 1,466 kg/ha). Whereas, in Jericho, the highest yielding accession (NGM-2) recorded 1.6 kg/7.5 m^2 (2,133 kg/ha) and the lowest (0.7 kg/7.5 m^2 or 933 kg/ha) yield were recorded for accessions NGM-11 and NGM-13 (Table 10).

Table 10. Quantity of sorghum grain produced by each landrace/ accession grown at Jericho and on Potchefstroom, 2021/22

No.	Accession Name	Grain quantity obtained (kg/7.5m²)	
		Potchefstroom	Jericho
1	NGM-9	1	1.4
2	NGM-10	1.1	1.3
3	NGM-11	0.8	0.7
4	NGM-12	1	0.8
5	NGM-13	0.8	0.7
6	NML-2	1.2	1.6
	AVERAGE	0.98 (1306 kg/ha)	1.08 (1440 kg/ha)

Presentation of the experimental results and handing over of seeds of the landraces/varieties to all three community seed banks took place in October 2022. The outcomes were presented to farmers on posters. The posters were prepared in graphs and/or tables so that they can easily be understood by farmers. The accessions which were selected by farmers based on their preference ranking and seeds of all rejuvenated varieties were handed over and placed in their community seed banks. 40 kg seed of the sorghum (Table 11) and 13 kg seed of the pearl millet (Table 12) landraces/lines multiplied at the ARC during the 2021/2022 season were shared among the three community seed banks. The National Genebank at the PGRC also received some of the multiplied seeds. 1.5 kg of cowpea and 1.5 kg of okra seeds were provided to the Jericho, Gumbu, and Sterkspruit farmers for seed increase, cultivation, and conservation in the community seed banks for future use.

Photo 11: Pearl millet harvested in Jericho.
Credit: Bioversity International/R. Vernooy

Photo 12: Feedback session in Sterkspruit.
Credit: DALLRD-NPGRC/R.P. Sema

Table 11. List of sorghum accessions and quantity of seed distributed to the three community seed banks (October 2022)

No.	Accession Name	Source of landrace/ accession	Seed quantity (kg)
1	NGM-3	Farmers' donation, Gumbu	5
2	NGM-4	Farmers' donation, Gumbu	2
3	NGM-6	Farmers' donation, Gumbu	3
4	NGM-7	Farmers' donation, Gumbu	2
5	NML-1	Farmers' donation, Jericho	3
6	1455.1.1.1	NPGRC	2
7	2055.2.1.1	NPGRC	4
8	3262	NPGRC	2
9	3281.1.1.1	NPGRC	2
10	3301.1.1.1	NPGRC	2
11	3319.1.1.1	NPGRC	4
12	4303.1.1.1	NPGRC	4
13	4312.1.1.1	NPGRC	3
14	5462.1.1.1	NPGRC	2

Table 12. List of pearl millet accessions and quantity of seed distributed to the three community seed banks (October 2022)

No.	Accession Name	Source of landrace/ accession	Seed quantity (kg)
1	NGM-9	Farmers' donation, Gumbu	2
2	NGM-10	Farmers' donation, Gumbu	2
3	NGM-11	Farmers' donation, Gumbu	2
4	NGM-12	Farmers' donation, Gumbu	2
5	NGM-13	Farmers' donation, Gumbu	2
6	NML-2	Farmers' donation, Jericho	3

Conclusion

The farmers expressed satisfaction with the results, including the participation in the research process, the learning about participatory variety selection, and the diverse seeds of good quality obtained as a result (Photo 12). The team and farmers agreed to address some of the challenges faced, e.g., lack of water/ irrigation facilities in all three community seed bank sites, lack of protective nets in Gumbu, need for fencing of the experimental field in Mbobo village, to allow continuation of activities at the three sites. The ARC will be available to offer advisory support to any challenges regarding seed rejuvenation and multiplication. The ARC will also continue to make its farm and research facilities available should there be a need in future. The PGRC will continue to provide technical support to the community seed banks.

4 MAIN ACHIEVEMENTS AND CHALLENGES

Credit: Bioversity International/R.Vernooy

Achievements

Overall, the main results achieved to date through our collaborative efforts with farmers in Gumbu, Jericho, and Sterkspruit, in support of farmer-managed seed systems in the country, are:

- Training staff of the National Plant Genetic Resources Centre (NPGRC) under the DALRRD (responsible for coordinating the implementation of the initiative) in the effective and efficient technical and organizational aspects of community seed bank management and exposure to concept and practice of participatory crop improvement (participatory variety selection in particular).
- Community seed banks established and functioning in three sites, and regular seed and knowledge exchange activities carried out among the community seed banks and between them and the PGRC and the ARC-VIM and ARC-GC.
- Increased knowledge and skills of smallholder farmers for the conservation and sustainable management of plant genetic resources in South Africa.
- Recognition of the roles of community seed banks in the conservation of plant genetic resources in South Africa, and technical, organizational and financial support to them, integrated in the strategy and operations of the NPGRC under DALRRD.
- Increased access to and availability of diverse, good quality seed and related knowledge by the three community seed banks.
- Training of farmers in participatory variety selection (PVS) and PVS field trials completed on cowpea, okra, pearl millet, and sorghum with positive results (knowledge and skills of participatory variety selection; increased crop and varietal diversity; increased seed supply of good quality seed).
- The accumulated experiences of establishing and supporting community seed banks in South Africa used to develop two community seed bank handbooks, one for facilitators (first published in 2017, later updated: Vernooy et al., 2020a; also available in French, Russian, and Spanish) and one for farmers (consisting of three booklets, first published in 2018, later updated: Vernooy et al., 2020b/c/d, also available in Arabic, Ateso, Bari, Chinese, Dinko, French, Luo, N'dogo, Nuer, and Spanish). The handbooks are used around the world by development and research organizations, and by farmers. See Box 1 for details.

Box 1

Community seed bank handbooks

Vernooy R; Sthapit B; Bessette G. (2020a) Community seed banks: concept and practice. Facilitator handbook (updated version). Rome (Italy): Bioversity International; Department of Agriculture, Forestry and Fisheries, Pretoria. Available: https://hdl.handle.net/10568/81286

Vernooy R; Bessette G; Sthapit B; Dibiloane A; Lettie Maluleke N; Abner Matelele L; Mokoena M; Phora G; Sema P; Thabo T. (2020b). How to develop and manage your own community seed bank: Farmers' handbook (updated version). Establishing a community seed bank: Booklet 1 of 3. Bioversity International, Rome, Italy. https://hdl.handle.net/10568/92000

Vernooy R; Bessette G; Sthapit B; Gupta A. (2020c). How to develop and manage your own community seed bank Farmers' handbook (updated version). Technical issues: Booklet 2 of 3. Bioversity International, Rome, Italy. https://hdl.handle.net/10568/92001

Vernooy R; Bessette G; Sthapit B; Porcuna Ferrer A. (2020d). How to develop and manage your own community seed bank: Farmers' handbook (updated version). Management, networking, policies and a final checklist: Booklet 3 of 3. Bioversity International, Rome, Italy. https://hdl.handle.net/10568/92002

- The handbooks are used for teaching and training purposes in several international courses coordinated by the Wageningen Centre of Development Innovation of Wageningen University and Research (The Netherlands) and the Alliance of Bioversity International and CIAT.
- The experience of South Africa stimulated the development of a protocol for formal collaboration between community seed banks and the national gene bank (or the national Plant Genetic Resources Centre), jointly written by the Community Technology Development Trust (CTDT); Seed Savers Network-Kenya (SSN); National Agricultural Research Organisation – Plant Genetic Resources Centre (NARO-PGRC); Wageningen Centre for Development Innovation, Wageningen University and Research (WCDI-WUR) and the Alliance of

Bioversity International and CIAT, which was published in 2021 by the ISSD Africa community of practice and the Alliance of Bioversity International and CIAT [https://hdl.handle.net/10568/111243].

- The work in South Africa was published nationally and internationally, and most recently included in the following book chapter:

Box 2

Vernooy R; Akhter F; Alonzo S; Mokoena ML; Mushita A; Otieno G; Shrestha P. (2021) Strengthening smallholder farmers' capacity to adapt to climate change: roles of community seed banks. In: Leal Filho W; Luetz J; Ayal D. (eds.) Handbook of Climate Change Management. Springer, Cham. First Online (09 March 2021). https://hdl.handle.net/10568/113053; DOI: https://doi.org/10.1007/978-3-030-22759-3_29-1

Challenges

Smallholder farmers in South Africa continue to face many challenges affecting their agricultural activities, including maintaining and strengthening of the community seed banks. In recent years, climate variability and extreme weather events have made it more difficult to know which crops/varieties to plant and when. Crop (and varietal) diversification can be an effective adaptive strategy and contribute to resilience (Sithole et al. 2022; Vernooy 2022), but it takes new knowledge and skills, time, and resources to adapt to the changing conditions. The pilot PVS activities carried out are a good start (although hampered in Sterkspruit by the impact of very bad weather), but much more can be done, e.g., experimenting with other climate-smart crops and varieties, improved soil and water management, developing value addition options for produce and seeds. Funds and technical support for these activities are needed.

Small groups of mostly elderly farmers (in Gumbu, mostly women) have kept the three community seed banks of Gumbu, Jericho, and Sterkspruit up and running. They have done so through voluntary time and effort, and with the technical, organizational, and financial support of DALLRD, ARC, and the Alliance of Bioversity International and CIAT. It has been difficult though to expand the membership, and, in particular, to engage the youth in the core activities of the seed banks. It has also been hard to find ways to generate some kind of income from the activities carried out, either as a remuneration for the hard work or an incentive to maintain the seed bank viable. These are (related) challenges that community seed banks around the world face. To engage the youth, a longer-term strategy needs to be put in place, e.g., through partnership with a local school or a (vocational) training centre in combination with value addition activities, e.g., processing of some of the local varieties into products that can be sold locally or regionally.

Although the three community seed banks have benefited from some institutional support through interactions with provincial/district agricultural departments, this has not taken the form of regular and continuous technical and organizational collaboration; let alone, financial support. Much remains to be done to integrate community seed banks in local agricultural development planning and implementation.

REFERENCES

Credit: Bioversity International/R.Vernooy

DALRRD (Department of Agriculture, Land Reform and Rural Development). (2017). National Plan (2017). National Plan for Conservation and Sustainable Use of Plant Genetic Resources for Food and Agriculture. Department of Agriculture, Land Reform and Rural Development, Pretoria, South Africa. https://bit.ly/3oGzTmY

Gómez César M; Sthapit B; Vernooy R. (2016). Safeguarding local crop knowledge: the use of community biodiversity registers. Bioversity International, Rome, Italy; Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa. http://hdl.handle.net/10568/78415

Maluleke N; Moila P; Phora G; Dibiloane A; Vernooy R; Sthapit B. (2014). Savouring diversity: first steps in implementing a strategy to support community seedbanks in South Africa's smallholder farming areas. Bioversity International, Rome, Italy, and Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa. https://hdl.handle.net/10568/56593

Matelele LA; Sema RP; Maluleke NL; Tjikana TT; Mokoena ML; Dibiloane MA; Vernooy R. (2018). Sharing diversity: exchanging seeds and experiences of community seedbanks in South Africa. Bioversity International, Rome, Italy and Department of Agriculture, Forestry and Fisheries, Pretoria, Republic of South Africa. https://hdl.handle.net/10568/96187

Mokoena ML; Sema PR; Maluleke NL; Tjikana TT; Dibiloane MA; Vernooy R. (2019). Strengthening community seed banks in South Africa. Bioversity International, Rome, Italy and Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa. https://hdl.handle.net/10568/105804

Sithole T; Shumba D; Otieno G; Vernooy R. (2022). Diversity and participatory crop improvement as conduit for climate change adaptation. ISSD Africa. https://bit.ly/3n1qqGf

Tjikana T; Dibiloane A; Maluleke N; Moila P; Phora G; Sthapit B; Vernooy R. (2016). Sharing diversity: establishing and supporting community seedbanks in South Africa (pilot phase 2013-2015). Bioversity International, Rome, Italy; Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa. http://hdl.handle.net/10568/78666

Upadhyaya HD; Pundir RPS; Gowda CLL; Reddy VG; Singh S. (2008). Establishing a core collection of foxtail millet to enhance the utilization of germplasm of an underutilized crop. *Plant Genetic Resources: Characterization and Utilization* 7:177–184. http://doi.org/10.1017/S1479262108178042

Vernooy R. (2022). Does crop diversification lead to climate-related resilience? Improving the theory through insights on practice, *Agroecology and Sustainable Food Systems*. http://doi.org/10.1080/21683565.2022.2076184

Vernooy R; Sthapit B; Tjikana T; Dibiloane A; Maluleke N; Mukoma T. (2013). Embracing diversity: inputs for a strategy to support community seedbanks in South Africa's smallholder farming areas. Report of field visits to Limpopo and Eastern Cape. Bioversity International, Rome, Italy, and Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa. https://hdl.handle.net/10568/105076

Vernooy R; Sthapit B; Galluzzi G; Shrestha P. (2014). The multiple functions and services of community seed banks. *Resources* 3(4):636–656. www.mdpi.com/2079-9276/3/4/636

Vernooy R; Sthapit B; Tjikana T; Dibiloane A; Maluleke N; Moila P; Phora G. (2016). Mobilizing diversity: establishment of the first two community seedbanks in South Africa's smallholder farming areas. Bioversity International, Rome, Italy, and Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa http://hdl.handle.net/10568/73242

Vernooy R; Shrestha P; Sthapit B. (2017). Seeds to keep and seeds to share: the multiple roles of community seed banks. In: Hunter D; Guarino L; Spillane C; McKeown PC. (eds.) *Handbook of Agricultural Biodiversity*. Earthscan, London, UK, pp. 580-591. https://hdl.handle.net/10568/90149

Vernooy R; Matelele LA; Sema RP; Mokoena MP; Maluleke NL; Tjikana T; Phora G; Dibiloane A. (2019). Green shoots. Community seed banking in South Africa: Endeavours and Outcomes 2016-2019. Bioversity International, Rome, Italy; Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa. https://hdl.handle.net/10568/101495

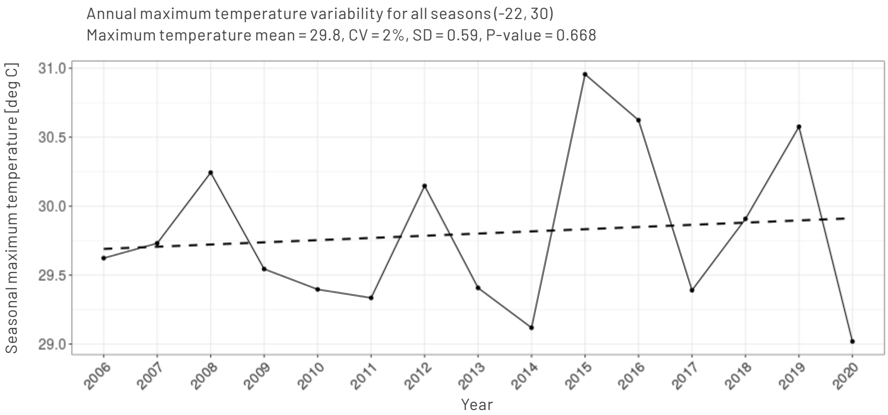
Vernooy R; Rana J; Otieno G; Mbozi H; Shrestha P. (2022). Farmer-Led Seed Production: Community Seed Banks Enter the National Seed Market. *Seeds* 1:164–180. https://doi.org/10.3390/seeds1030015

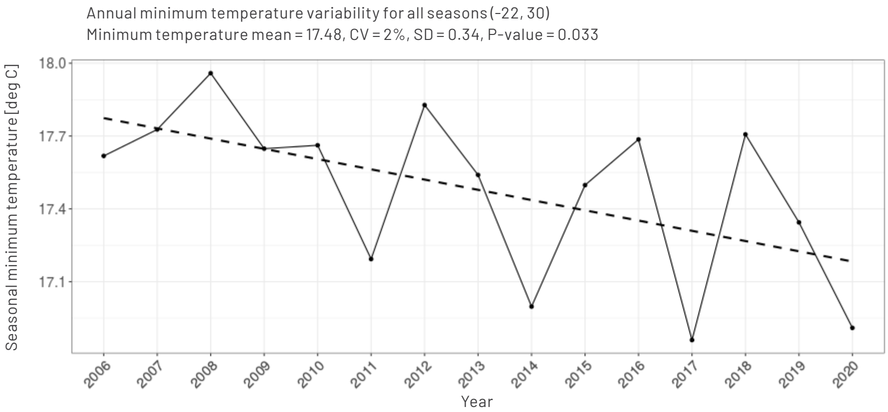
ANNEX 1

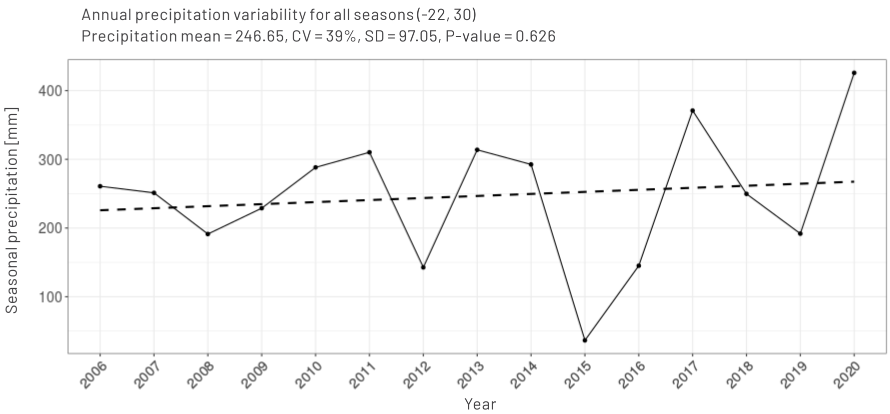
Weather patterns 2006-2020 of Gumbu, Jericho, and Sterkspruit

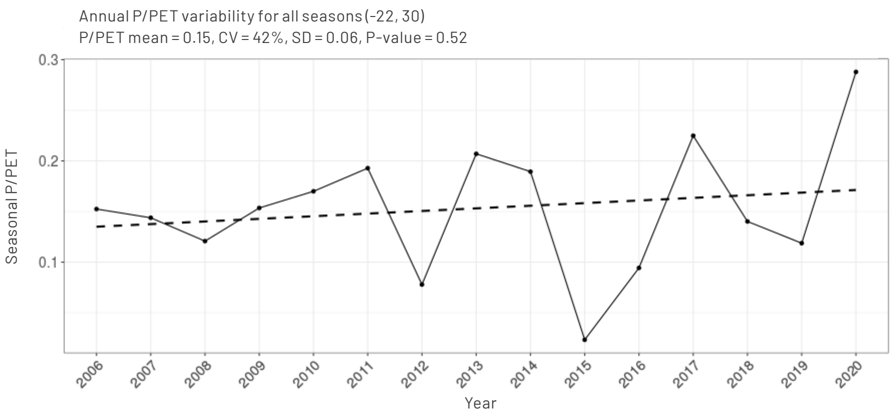
Gumbu

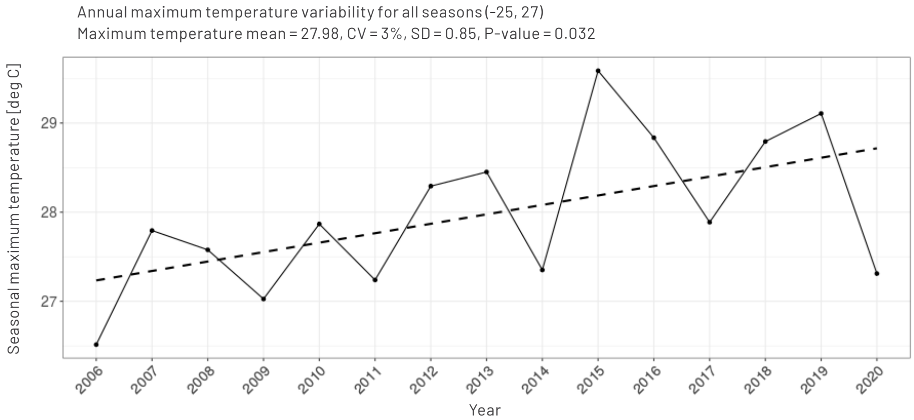
Source: aWhere Weather Apps, accessed March 2021







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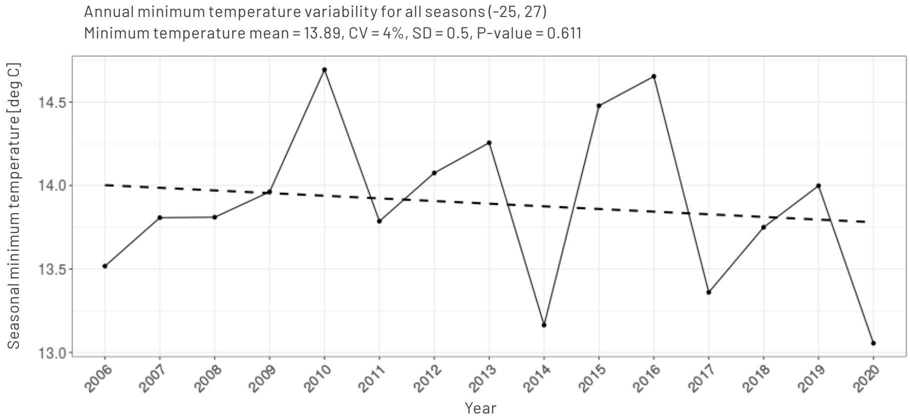
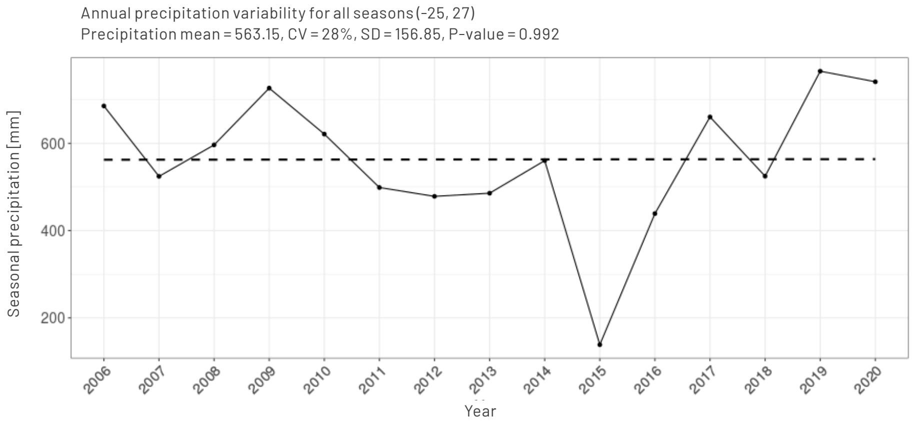
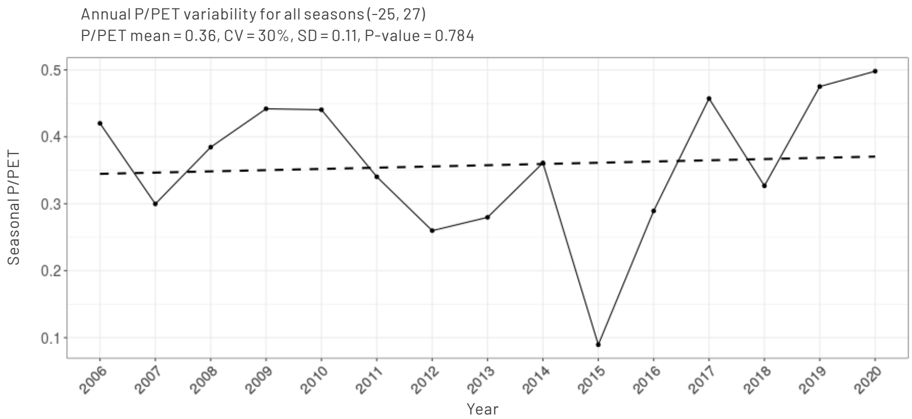
Maximum temperature mean = 27.98, CV = 3%, SD = 0.85, P-value = 0.032
Seasonal maximum temperature [deg C]
Year

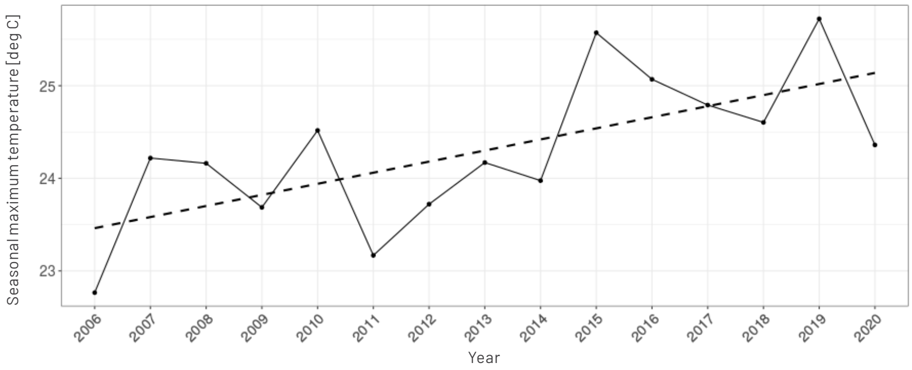

Annual minimum temperature variability for all seasons (-25, 27)
Minimum temperature mean = 13.89, CV = 4%, SD = 0.5, P-value = 0.611
Seasonal minimum temperature [deg C]
Year


Annual precipitation variability for all seasons (-25, 27)
Precipitation mean = 563.15, CV = 28%, SD = 156.85, P-value = 0.992
Seasonal precipitation [mm]
Year

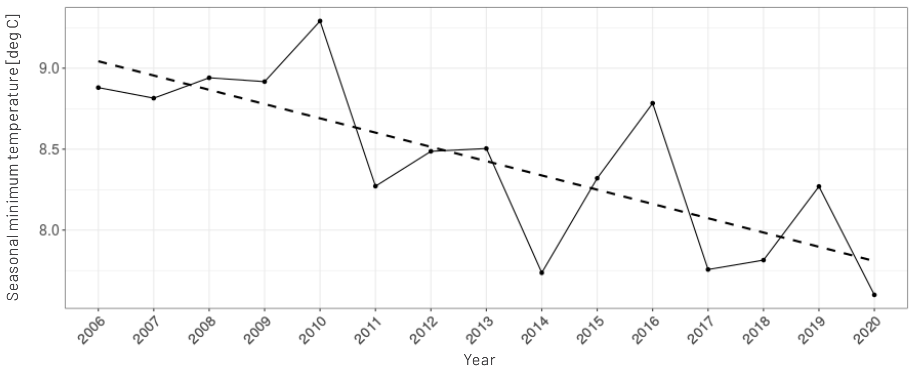

Annual P/PET variability for all seasons (-25, 27)
P/PET mean = 0.36, CV = 30%, SD = 0.11, P-value = 0.784
Seasonal P/PET
Year

Sterkspruit

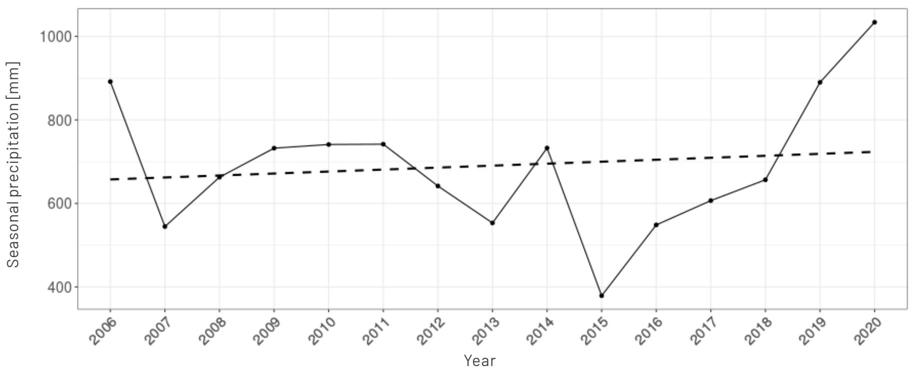
Annual maximum temperature variability for all seasons (-30, 27)
Maximum temperature mean = 24.3, CV = 3%, SD = 0.81, P-value = 0.007



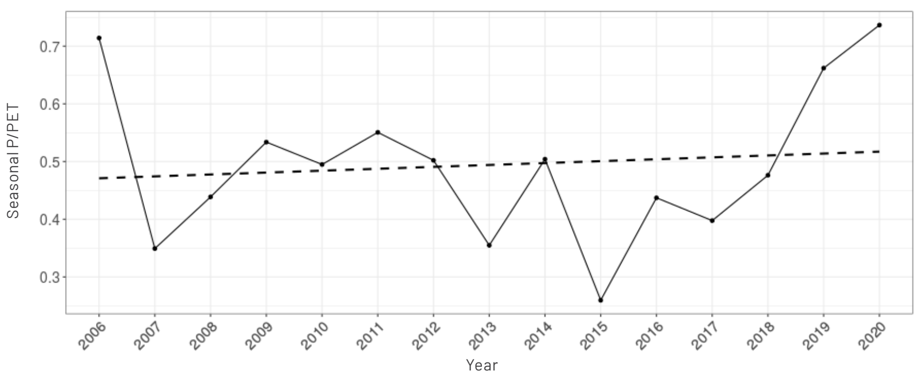
Annual minimum temperature variability for all seasons (-30, 27)
Minimum temperature mean = 8.43, CV = 6%, SD = 0.52, P-value = 0.001



Annual precipitation variability for all seasons (-30, 27)
Precipitation mean = 690.47, CV = 24%, SD = 163.8, P-value = 0.647



Annual P/PET variability for all seasons (-30, 27)
P/PET mean = 0.49, CV = 27%, SD = 0.13, P-value = 0.696

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