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Genetic resources management, seed production constraints and trade performance of orphan crops in Southern Africa: A case of Cowpea

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ABSTRACT

Despite the contribution of cowpeas to food security and the crop's numerous nutritional and health attributes, consumers in South Africa have labelled cowpeas, among other leguminous crops as a *"poor people's food"*; this contributed to the gradual decline in the cultivation and use of the crop. This, in turn, resulted in the observed high reliance on limited number of plant based protein crops and excessive consumption of livestock products. In this paper, three aspects are interrogated, i.e., genetic resource management, production constraints as well as the trade performance and consumption of cowpeas in South Africa. A clear understanding of these aspects renders an informed decision upon which recommendations for the necessary practical interventions that are needed to be put in place to spur the development of target products and cowpea's value chain. The assessment of genetic resource management and seed production constraints of cowpeas was based on a review of relevant literature, while descriptive analysis of secondary data spanning a period of 10 years (2010-2019) obtained from Trade Map and FAOSTAT databases was used to interrogate the trade performance and consumption of cowpeas. Findings reveal that seed production constraints are largely anchored on the limited attention government and policy making institutions have accorded to the seed system of orphaned crops, thereby compromising their potential by failing to supply affordable good quality seeds to smallholder and commercial farmers. However, South Africa has one of the largest and most diverse collections of cowpea germplasm housed at the Agricultural Research Council. With regard to trade performance and consumption, results show that South Africa is a net exporter of cowpeas, with a 10 years' period annual average worth R2.9 million. Given that South Africa does not re-export cowpeas, yet on average 4848 tonnes are produced annually, it is a clear indication that the country produces lightly more than what is consumed domestically – on average 4634 tonnes per annum. Therefore, recommendation is made to bolster cowpea production and productivity through mainstreaming the legume seed system towards boosting local and export markets as well as strongly enhancing local consumption by creating awareness of the nutritional and health benefits of cowpeas. Furthermore, there is a need to increase awareness about the nutritional and health benefits of cowpeas and other leguminous crops, among other socio-economic benefits. This is important in spurring cowpeas consumption domestically, while countering the over reliance on animal products as protein sources and the associated risks such as such as high greenhouse gas emissions and obesity for people.

1. Introduction

Indigenous legume crops such as cowpea [*Vigna unguiculata* (L.) Walp], are crops of strategic importance in fostering food and nutritional security, trade and income generation, while enhancing sustainable agro-ecosystems (Ojiewo *et al.* 2018; Mahlangu et al. 2020). Because of their nutritional and health attributes, indigenous legumes are also used globally as preventative and control remedies for a number of diseases (Thumbrain et al. 2020; Tchuenchieu and Kesa, 2020; Gondwe et al. 2019; Mtolo et al. 2017; Taruvinga and Nengovhela, 2015). For instance, cooked cowpea seeds are traditionally used in South Africa to treat blood in urine and bilharziasis (Van Wyk and Gericke, 2000, cited in Thumbrain et al. 2020). Unfortunately, in South Africa, Cloete and Idsardi (2013) and Akinola et al. (2020) reckon that consumers have labelled indigenous crops as "*poor people's food*"– cowpeas inclusive, despite the fact that they require less resources to produce (Mahlangu et al., 2020) compared to cereal crops.

The labelling of indigenous crops as "*poor people's food*" and the improving socio-economic status of people in part explain the

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observed high reliance on and consumption of animal products as the major source of protein in South Africa (Mabhaudi et al. 2019), among other socioeconomic and cultural factors. The net human per capita consumption of white meat had increased by 97% in the 2018/2019 financial year from 21.48 kilogram (kg) per year in 2000/01, reaching 42.32 kg per person per year., while red meat consumption had reached 26.24 kg per year, an equivalent of 38.4% increase during the same period (Abstract of Agricultural Statistics, 2019). According to Delport et al. (2017) and DAFF (2016), chicken meat is the cheapest and most consumed source of animal protein and it accounted for 59% of meat consumed in 2015. In 2016, broiler meat consumption was 40 kg per person per year compared to 22 kg per person in 2000 (Oirere, 2019). Delport et al. (2017) reported that the increase in meat consumption at the expense of traditional food stuffs in developing countries has become known as the *Livestock Revolution*.

Over-dependence on animal products as sources of protein not only presents health risks such as overweight, obesity, diabetes, and cancer (Spires *et al*., 2016) but also raises a concern of the extent to which the current livestock production systems can sustainably supply animal products. There is further challenge to meet the growing demand, amidst production challenges – including the high cost of feeds, which accounts for more than 50% of production costs. For broiler chickens, Davids and Meyer (2017) report that feeds account for 71.3% of the total variable production costs. Another challenge relates to the high greenhouse gas (GHG) emissions, whereby livestock contributes between 5.5% and 6% of the total agricultural GHG emissions, beef cattle being the largest contributor, followed by sheep and dairy cattle (Faber, 2020; Scholtz et al. 2013). To reduce agricultural GHG emissions, Quinn et al. (2011) recommended the shifting towards plant-based food systems which would represent a potential reduction of food-related GHGs by 29%-70%.

In addition, the negative health effects of the generally limited dietary options for South Africans are well documented and the impact of this is particularly severe on the poor (Van Heerden and Schönfeldt, 2011; Claasen et al. 2016). Gerrano et al. (2018) note that cowpea is a neglected and underutilised crop in South Africa. Little information pertaining to a poor seed system causes production constraints, thereby affecting the seed system, genetic resource management, as well as the trade performance and consumption of cowpeas in South Africa is available and accessible. This paper therefore seeks to answer three questions: (*i*) what production constraints affect South Africa's seed production system for orphaned crops, (*ii*) how are genetic resources of orphan crops managed in Southern Africa? and (*iii*) what is the trade performance and consumption trend of cowpeas in South Africa? A deeper understanding and knowledge of the seed production constraints, genetic resource and agronomic management, as well as the trade performance and consumption trend is important in designing and developing interventions through which the domestic consumption of cowpeas can be bolstered, thus countering the over reliance on animal products as protein sources and the associated risks including reducing cholesterol, decreasing blood sugar levels, diabetes as well obesity.

The paper also explores the rationale behind the reliance on animal products visa-á-vis indigenous legumes, as well as a description of genetic resource management and the seed system with emphasis on production constraints. The subsequent section describes the methodology used and the discussion of results while the last section provides a conclusion and some practical recommendations.

2. Agronomic management and breeding of cowpea

Cowpea has a significant potential for sustainable development solutions and is widely grown under low input crop production systems in arid and semi-arid agro-ecologies of the world. The crop diversifies farming systems and have the potential to contribute to food and nutritional security and alleviate poverty, increase income and improve human health (particularly malnutrition and lack of micronutrients). This will require sustainable food crop production systems and resilient crop production management practices, equal access to land, technology and markets and international cooperation on investments in infrastructure and technology to boost agricultural crop productivity (United Nation, 2019). In South Africa, large producer of cowpeas are small-scale farmers under dryland farming conditions (DAFF, 2011; Gerrano et al, 2019) with a limited production area which produce 0.5 t ha^{-1} as compared to the potential yield of 3.0 t ha^{-1} (Asiwe, 2009). This leguminous crop is said to be a valuable component of the farming systems of the smallholder farmers in the country (Gerrano et al. 2019). Cowpea growing Provinces in South Africa are KwaZulu-Natal, Limpopo, Mpumalanga, Eastern Cape and North West. These provinces are ear marked to have shown interest in growing this crop plant (DAFF, 2011) in the country. The production of cowpea plant is limited in South Africa due to the following factors including low productivity of the genotypes available at the farmer's level (landraces), moisture stress, absence of improved cultivars for high yielding and nutritional composition, low fertility of the soil, losses of yield due to insect pests and disease (Gerrano et al. 2019; Mofokeng and Gerrano, 2021) and hence improvement of these limiting factors through breeding and application of adequate and precision agronomic management practices of cowpea plant enhances the yield. Furthermore, the low productivity of this crop is aggravated by lack of access to appropriate resources like fertilizer and credits. Some of the agronomic management practices that may increase cowpea productivity are optimal plant population, appropriate planting time, good soil type, efficient management of nutrient, the use of fertilizers, fallows and rotations, supplemental irrigation, integrated pest, disease and weed management and suitable cropping system (Evans and Fisher, 1999; Kamara et al. 2018; Siddique et al. 2012). Similarly, Ajeigbe et al. 2010; Kamara et al. 2018; Asiwe, 2009 and Gerrano et al. 2019 reported that cultivation of this crop plant is mainly performed under traditional production systems by the small-scale farmers as a result the grain yields low (0.025-0.3 t ha^{-1}). This indicated that intensive breeding work should be done in developing cultivars with improved yield potential, disease and insect resistance of the crop in the country to increase the production and productivity of cowpea for food security.

Cowpea is under researched crop in Southern Africa and is grown mainly by subsistence farmers for its plant parts for human consumption. It is widely distributed in regions of tropical and temperate climates, thus differing morphologically (shape, size, colour of seed coat) and in proximate composition, hence effecting physicochemical characteristics. Collection, characterization, evaluation and parental identification of cowpea germplasm accessions is a pre-requisite in plant breeding programme globally. A pre-breeding programme of cowpea is actively progressing which aims to lead to a full-scale crop improvement programme in the Southern Africa including South Africa, Namibia, Malawi, Zambia, Mozambique, Botswana and Zimbabwe with the main objectives of genetic diversity analysis using agro-morphological characterization of imported germplasm accessions, breeding for high yield, nutritional profiling and breeding for quality in different parts of the plants (leaves, green pods and seeds), identification of disease and pests towards breeding for diseases and pest resistance, stability over environments, breeding for drought tolerance and selection of parental lines for development of new cultivar through farmers participatory breeding for preferred traits of interest.

3. Why the high demand and consumption of animal products unlike the indigenous legumes – e.g., cowpeas in South Africa

Despite the high diversity in food based items that are good sources of protein among other benefits, attention has been accorded to a

selected few (especially meat products). This presents a risk of further affecting the status of dietary diversity and food security in the country, as well as trade and income security. Contributing factors for neglecting cowpeas and other indigenous legumes as protein sources in favour of animal products include the following: First, the chemical composition of cowpeas and other legumes, *i.e*., the existence of anti-nutrients such as trypsin inhibitors and condensed tannins. Trypsin inhibitors hinder activities of digestive enzymes, while condensed tannins inhibit protein digestibility, hence interfering with the bio-availability of amino acids (Gerrano et al. 2019; Unigwe et al. 2018). Jaichand et al. (2020) report that boiling is one of the most effective processing techniques used to reduce anti-nutrients. However, research by Akindahunsi and Salawu (2005) reveals that low concentrations of tannins are also advantageous given that it has numerous nutritional and health benefits in animals and humans, especially in the control of internal parasites. The pre-breeding efforts involving cowpea have been directed towards the full-scale characterization of including agro-morphological, nutritional, and phytochemical and antioxidant properties for the full-scale breeding programme at national level in South Africa. The current COVID-19 pandemic affected the production of food, health and nutritional security as a result of constraints to the production and distribution of farm products, travel restrictions and reduced purchasing power especially small scale farmers community in the rural areas of South Africa. Hence, development of new cultivars for high yield and nutritional values is critically important that can boost the immune system of the human body. Related with poverty are food shortages and poor nutrition that affect many households in both urban and rural areas in South Africa. Poor nutrition is lack of macro- and micronutrients as well as essential vitamins with resulting impacts on health and well-being. Therefore, the nutritional and health significance of the crop suggests the needs for cultivar development through breeding for high yield and yield contributing traits as well as biofortification breeding and quantify agro-nutritional, and phytochemical compositions in this crop for genetic enhancement of the traits of farmers demand driven product traits for effective improvement programme in the future. This could enhance in increased yield and yield contributing traits through hybridization and bioavailability through biofortification especially for micronutrients concentration (iron, zinc and protein).

Second, because of their chemical composition, legumes generally get spoilt so quickly after harvest. This compels value chain actors to shy away from taking a risk to invest in cowpeas and other legumes in general, except if they have appropriate means of storage and transportation (Sperling and McGuire, 2010). Third, the limited availability of good quality seeds compromises the realisation of better yields, which could be one of the reasons for the low and in some instances non-availability of indigenous legumes crops in modern markets/shops as reported by Omotayo and Aremu (2020) and Mbhenyane (2017). Fourth, the wrong perception that indigenous leguminous crops in general are consumed by poor people in rural communities (Mahlangu et al. (2020); Kansiime et al. 2018; Cloete & Idsardi, 2013). This may be exacerbated by the limited attention policy-makers and technical experts accord to research, development and promotion of these crops (Ojiewo et al. 2018). Moreover, indigenous leguminous crops have been wrongly labelled as weeds (Akinola et al. 2020), which has negatively affected their acceptance and consumption particularly amongst the youths. Ojiewo et al. (2018) report that legumes have also been broadly categorised as "*non-cash crops*" yet they even command higher prices in local markets than the renowned traditional cash crops. A study undertaken in Kenya revealed that consumers were actually willing to pay about 79% more as a premium price for African leafy vegetables (Chelang'a et al. 2013).

Fifth, the changing food production systems, increased consumer awareness, urbanisation and better means of transport, which enable easier access to food products sourced from beyond the local communities (Montanari, 1994; as cited by Cloete and Idsardi, 2013). Conversely, Mabhaudi et al. (2019) reckon that although the new food production is associated with increased food production, availability and accessibility it is also credited for the exacerbating malnutrition, biodiversity loss and environmental degradation. Sixth, there is limited transfer of knowledge and information pertaining to indigenous leguminous crops from one generation to another (Kansiime et al. 2018; Vorster et al. 2008); it is for this reason that these crops are sometimes referred to as "*lost and found*". The limited knowledge and information relate to the extent of their use and relevance in communities. Lastly, the historical apartheid era during which the indigenous people had restricted access to land (Pereira and Drimie, 2016) and were relocated from their original communities, thereby distorting the use of indigenous crops and knowledge linked to them (Akinola et al. 2020). This further changed and modified the socio-cultural setup of the South African food system, making it the least diverse compared to other African countries (Mabhaudi et al. 2019). In this regard, the way the agricultural products market is set up in South Africa (strict regulatory, quality, quantity and exorbitant market agent fees requirements) plays fundamental role in hindering the entry of indigenous crops to the market (Drimie, 2016; Mabhaudi et al. 2019).

Conversely, the high demand and consumption of animal products is driven by the fast-growing urban population. In urban areas, usually with better infrastructure as compared to the rural communities, there is a higher density for food provision thereby enabling consumers to easily gain access to high value animal products and other processed food stuff produced far away from their local community. South Africa has many large urban informal settlements, which rely on the informal trade sector for food supplies (Rudolph et al. 2012; Battersby, 2011; Crush et al. 2011). The informal trade sector is advantageous for the urban poor through: providing meat cuts that meet cultural preferences, offering affordable unit sizes, operating for long opening hours, restocking fresh produce on regular basis and offering consumers food items on credit, among others benefits. However, it is also disadvantageous in the following aspects: non-perishable goods are generally more costly and it offers a limited range of foods perceived to be of lower quality (Kroll et al. 2019), such as cowpeas among other indigenous legumes.

The observed drastic upsurge in meat consumption amongst South Africa's consumers in the past two decades is also attributed to increased disposable incomes amongst consumers. Thus, as South Africa's consumers move towards higher income groups (the middle class), they are fond of protein-filled diets rather than starch-based diets (Delport et al. 2017, USDA FAS, 2015, Steinfield et al. 2006). In 2014, consumers spent one third of total food expenditure on meat products only, an equivalent of R165 billion, which is about 4 folds higher than the expenditure incurred on meat products in 2004. Other factors driving the high demand and consumption of animal products include: competitively priced products, valued added products and products of convenience that require less time to prepare (USDA FAS, 2015). Hence, there is a need to develop cowpea germplasm and product that meets the market demands that can contribute to food and nutrition security.

4. Constraints of an under-developed seed system affecting production and productivity

Seed is one of the most economical inputs for agricultural research and development as well food security. It is the basic unit of crop production (Louwaars, 2007). Seed producers and consumers can select the varieties, which are adapted to their respective agro-ecological conditions. Furthermore, access to quality seed is an important step in increasing smallholder production and productivity. It is therefore, important to have mechanisms that would help in

the understanding of the systems in place that produce quality seeds and deliver appropriate and demand led seed varieties in a timely manner to farmers (Iorlamen et al. 2021). Variety use and development, seed production and storage by farmers under local conditions, and seed exchange mechanisms will benefit in income generation, food and nutritional security (Kouyate et al. 2021).

Furthermore, the identification and cultivation of genetically superior plant material embodied in seed can result in higher and stable crop yields, lower losses due to pests, disease, and adverse weather conditions (van Etten et al. 2019). Hence, ensuring reliable access to improved cowpea cultivars for high yield potential, pests and disease resistance requires the establishment of seed systems that are able to develop improved varieties farmers require. The seed system should also multiply high-quality seed of these varieties (Louwaars and de Boef, 2012), and distribute the seeds to farmers in sufficient quantities on time with affordable price (Kouyate et al. 2021). The farmers-extension participation plays a major role in informed decision on the availability and adequate input requirement as well as up-scaling the best practices to increase farmer experience and knowledge about input potential for production. Kouyate et al. (2021) reported that sustainable production of cowpea requires optimized use of quality seeds of improved varieties, good agronomic practices, and agricultural fertilizers towards development of more effective and efficient commercial marketing channels for the cowpea seed value chain. Quality seed is not only the most basic inputs in crop production system, but it also influences how the crop itself in question responds to all other growth and development factors that contribute to successful cowpea value chain.

Despite the benefits associated with a well-functioning seed system, the following constraints have been reported to affect Southern Africa system.

First, the weak public seed system which renders access to good quality seeds of new improved varieties that meet the demands of the domestic and export market is a challenge. Availability, cost and quality of seed are the key determinants of production success in crop-based agriculture. The indigenous crops seed systems in general and the legume seed sector in particular has not received sufficient government attention it deserves. For example, in the East African region, Ojiewo et al. (2018) report that there is lack of policy support for input and output markets of legume seeds as compared to cereal crops which receive stronger policy support. This situation is not different in South Africa and Southern Africa in general. This has rendered farmers to mostly use their own seeds while the private sector has minimally participated in the marketing of legumes seeds – in part due to their high self-pollinating nature. Own seed and that sourced from informal channels is problematic with regard to purity, viability and productivity (Ojiewo et al. 2018). Problematic seeds inevitably limit the realisation of better yields, hence making cowpea and other indigenous legumes production seem to be not worthwhile options for investment by the various players in the value chain.

Second, unlike cereal crops, legumes in general have not received much investment for breeding, hence the limited availability of good quality seeds. In addition, because of their chemical composition, legumes generally get spoilt so quickly after harvest. This is therefore a contributing factor for the value chain actors to shy away from cowpeas and other legumes in general, except if they have appropriate means of storage and transportation (Sperling and McGuire, 2010). For instance, in the ARC gene bank, the cowpea seeds are stored with the temperature-regulated storage units. The seeds, which are intended for both base and active collections are dried to 3-7 per cent moisture content and are maintained at -10°C in laminated aluminium foil bags and plastic jars. However, subsistence farmers in South Africa are not in position to undertake the above stated technical procedures and conditions, hence they maintain cultivars of indigenous crops inclusive of cowpea on-farm (National Department of Agriculture, 1995). The ARC gene bank provides planting materials to the farmers during farmers participatory breeding that have been done at the farmers field. Among other critical factors affecting the seed system for legumes, there is the challenge of undertaking large scale mechanised production activities, as elaborated by (Ojiewo et al. 2018).

5. Genetic resources management

Most countries in Southern Africa have national genebanks and most crops, wild crop relatives and wild useful plants have been collected and conserved for the future use. On-farm conservation activities linked to ecological farming systems are practiced in some countries including South Africa. Some countries have Community Seed Banks for the provision of planting material at the earliest convenient time to farmers and semi commercial as well commercial farmers. What is lacking is the development of policies that will support commercialization of farmer varieties. There is need to characterize and evaluate crops with adaptable and preferred traits, sell them as they are and improve those that require genetic enhancement through breeding.

Currently, there is a larger war on seed ownership in African content as well as globally. Most of cereal seeds including legume seeds are owned by big seed companies. Hence, indigenous and rural people are being prevented from growing their own seeds due to the replacement of farmers landraces by improved cultivars indicating that the current increased food crop production has resulted in a significant decline in landrace genetic diversity since modern high-yielding crop varieties and highly nutritionally profitable crops are preferred by urban farmers over indigenous and traditional food crop varieties. Therefore, collection and preserving indigenous food crops as well as native seeds with their respective uses will help in the development of improved population/cultivars. The setting up of community seed banks for underutilized and forgotten foods would go a long way in bringing these foods back to the table in different parts of the country in Africa and beyond. Such seed banks will help as training centers specifically in underutilized and forgotten foods while preserving biodiversity in the phase of climate change.

Despite its relatively developed status compared to other African countries, South Africa is characterised by narrow food base where there are not much to choose from. Amongst the legume crops, common bean, peas and soybean are the most commonly cultivated. As a result, these crops have obtained attention for both genetic resources management and development of sustainable seed system. Similarly, if South Africa is to expand its choices of leguminous (plant-based protein) crops, development of effective genetic resources management that supports both crop development research as well as establishment of seed systems is imperative. Cowpea is one of the popular crops in other parts of Africa and enjoys research support through institutions such as International Institute of Tropical Agriculture (IITA) and CGIAR; but this is not the case in South Africa despite the growing importance of the crop.

The largest and most diverse collections of cowpea germplasm in the world is housed at IITA in Nigeria. The total number of germplasm collected and maintained in the gene bank of IITA are over 31,000 including cowpea, cassava, plantain and banana, yam, soybean, bambara groundnut, sorghum and maize, among which the total number of cowpea collections are 16 000 accessions from 88 countries, representing 70% of African cultivars and nearly more than half of the global diversity (IITA, n.d https://www.genesys-pgr.org/wiews/NGA039). Furthermore, the IITA reported the existence of collection of cowpea wild relatives and miscellaneous legumes) in the gene bank. Hence, the IITA cowpea collections play a great role in providing the germplasm collections for different international and national research institutions for research and development worldwide.

In South Africa, the total collection of cowpea germplasm in the Agricultural Research Council (ARC) gene bank are about 1200. These are sourced from field collection, and acquisition from the national and international sources for conservation and subsequent utilization in the research and development system in the country. The ARC imported different germplasm of cowpea from IITA and World Vegetable Center for research and development purposes as well as for broadening the gene pool of cowpea in the country which indicated that the cowpea breeding efforts are mostly successful and effective when there is access to plant genetic resources from various countries around the world. The ARC cowpea collections provide the platform for the international partners in research. Currently, the Bioversity International and International Atomic Energy Agency are collaborating with the ARC on the cowpea collections in research in South Africa indicating that there is close interaction with the international companies to conserve and share plant genetic resources for food and agriculture. The cowpea collections are often requested by several small scale farmers and private clients at national and international levels. The need for conservation of plant genetic resources including cowpea has become increasingly urgent due to the rapid genetic erosion and loss of naturally occurring genetic diversity on the planet. Therefore, the management of plant genetic resources is the basis for agricultural research and development systems in terms of genetic resources maintenance in the *in situ* and *ex situ* conservation systems (Smale et al. 2010; Sidibe et al. 2015). Plant genetic resources collection, characterization, evaluation and selection are prerequisite in the breeding programmes for registration, population development and release. It was reported that conservation of crop plants in the *ex situ* and *in situ* is the conservation method of choice to prevent extinction of natural plant populations (Benz, 2012; Barkley et al. 2016) for future use in breeding programmes.

The crop plant genetic resources generally help in food, nutritional, health, shelter and income generation benefits (Kouyate et al. 2021) for alarmingly increasing world population and adaptability for the current and future climate changes that affect the agricultural production system. Hence, conservation and sustainable use of crop plant genetic resources including the farmers landraces are important to feed a predicted population of 9.8 billion by 2050 (United Nations, 2017). Crop varieties such as cowpea have long been evaluated, selected and pollinated by the farmers to develop new cultivars based on the farmers participatory variety selection. Breeders select varieties based on their desirable traits of interest including high yield, pest and disease resistance, tolerance to abiotic stresses, and nutritional quality attributes preferred by the end users and other seed stakeholders in the value chain of the crops (Tanto and Tefera, 2003; Gerrano et al. 2015). The conservation of legume crops including the existence of diverse cowpea germplasm provides the basis for selecting suitable types with desirable traits for breeding programmes.

The collected accessions of cowpea germplasm (landrace and improved cultivars) are subjected to agro-morphological characterization, adaptation and diversity studies at the multi environmental conditions and laboratory environments for the desirable traits (Souza and Sorrells 1991; Gerrano et al. 2015) for selection and recommendation for use by the farmers in Southern Africa. Moreover, molecular diversity analysis is also important for the improvement of cowpea germplasm to understand the associations between and among the germplasm accessions and the geographical locations as well for the improvement programme (Souza and Sorrells 1991; Tanto and Tefera, 2003). The potential importance of collection of cowpea germplasm, conservation, seed system research and linking these to the market system (value chain) and breeding improved varieties for cultivation could be intensively explored for food, nutrition and health benefits in South Africa in particular and at large in sub Saharan Africa. Current research and development policy in South Africa supports the collection and conservation of underutilised crops. The need to broader the local food base and the global change in food consumption pattern where there is increasing demand for indigenous foods of African and Asian origin (Imamura et al 2015). As the demand from civilised nations increases, the need for conservation and use of indigenous and indigenised foods will increase due to the market demand. It is for these reasons that market information of a particular crop cannot be discussed without the determinants of production such genetic resources management, breeding and seed systems. Discussing the market and production potential of cowpea within the context of production constraints is therefore, imperative.

6. Methodology for the trade status determination

The literature reviewed in preceding sections provides an insight into the production constraints affecting the seed system and how genetic resources for orphaned crops, particularly cowpeas are managed in Southern Africa. Subsequently, to assess South Africa's trade performance in cowpeas, descriptive analysis based on secondary data obtained from TradeMap (2020) spanning from 2010 until 2019 was used. We used trade balance as a measure of trade performance. The trade balance, also known as the commercial balance refers to the difference between exports and imports of a given country for a specific period (Kenton, 2020). A negative trade balance means that the country is importing more than what is exported, hence a bad trade performance and the reverse is also true. To ascertain the consumption trend, descriptive analysis based on data extracted from FAOSTAT (2020) was used. Notably, available data for cowpeas used for food supply span from 2014 to 2018.

7. Results and discussion

It has been reported that the cowpea crop is an important plant based protein and nutritional legume crop in Africa covering eastern, Southern and western regions including Ethiopia, Somalia, Kenya. Tanzania, Mozambique, Zambia, Zimbabwe, Botswana, Nigeria, Niger, Mali, Senegal, Rwanda, and Burundi (Amable and Rugambisa 1992). It is also cultivated in the Southern African regions as a pure crop and as a mixed crop with different cereal crops such as maize, sorghum and finger millet. The crop is consumed both as grain and vegetable in the form of green pods and the tender leaves are regularly picked and eaten as spinach in east and southern Africa (Mortimore, et al., 1997; Gerrano et al., 2019). Results reveal that South Africa exhibits a positive trade balance, implying that the country exports more cowpeas than what is imported. This suggests South Africa produces enough cowpeas (on average 4848 tonnes per year) to meet the current domestic demand for food supply. Notably, FAOSTAT (2020) reveals that about 7.8 tonnes of cowpeas on average per year are used to make animal feeds. Thus, the largest proportion of cowpeas in South Africa is used for human consumption. Table 1 summarises South Africa's trade performance and consumption considered in this paper, among other selected indicators.

The trends illustrated in Figure 1 reveal that cowpeas consumption increased by 5% between 2014 and 2018 while production dropped by 2% during the same period. The increase in consumption may be attributable to the prolonged drought which negatively impacted on South Africa's agricultural sector (BFAP, 2019; Ntombela et al. 2017). Due to the drought, the price of meat products spiked given that it took a long time for farmers to rebuild the animal herds since a number of animals had either died and, in some instances, farmers sold off the animals that they could no longer sustain during the prolonged drought (Stats SA, 2017c; Mare et al. 2018; Oirere, 2019). The spike in prices compromised consumers' affordable access to animal products. However, as an alternative source of protein, consumers opted for cowpeas, among other indigenous

Table 1
Descriptive statistics of selected indicators for South Africa's cowpeas

Description	Number of years (n)	Mean (St. Dev)	Minimum	Maximum
Trade balance (R'000)	10	2998.9 (3733.2)	-2107	8515
Export (tonnes)	7	499.6 (276.9)	220	1079
Production (tonnes)	10	4848.3 (112.3)	4600	5000
Human consumption (tonnes)	5	4631.8 (93.8)	4511	4749
Animal feed (tonnes)	5	7.8 (0.45	7	8

Note: St. Dev denotes Standard deviation. Sources: TradeMap (2020), FAOSTAT (2020)

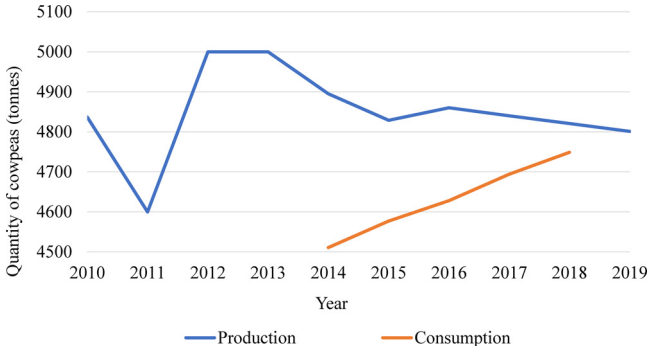

Figure 1. Production and consumption trends of cowpeas in South Africa Source: Author's compilation based on data extracted from FAOSTAT (2020)

vegetables and hence the increased consumption growth rate against a declining production rate.

Due to the impact of the drought, FAOSTAT database shows that the opening stocks for cowpeas dropped by 69% between 2014 and 2018, while the average stock also decreased by 145 tonnes per year. The argument that the increase in cowpeas consumption was associated with the prolonged drought concurs with Statistics South Africa (Stats SA) (2017a; 2017b; 2017c) who reported that the within a twelve months' period (August 2016 – August 2017), meat prices increased by 15% while the prices of vegetables (inclusive of cowpeas) declined by 3.6% in the first eight months of 2017. Mahlangu et al. (2020) also reported that many developing countries are working towards enhancing consumption of indigenous legumes.

8. Conclusion, recommendation future prospects

Cowpeas, among other indigenous legumes have been labelled as a "*poor mans' food*", rendering consumers in South Africa to focus more on animal products as the major sources of protein. From the findings, it clear that South Africa produces more cowpeas than what is consumed on the domestic market, hence the surplus is exported. Despite being labelled as a "*poor man's food*", there is an increasing demand for cowpeas for human consumption and a small proportion being used to make animal feeds. It can also be concluded that cowpea is an alternative source of protein especially during situations when animal protein sources are less accessible or affordable, e.g., during the prolonged drought experienced between 2014 and 2016. All the above present market opportunities for South Africa to further develop the underutilised cowpea value chain.

Based on the reviewed literature and empirical findings, the following recommendations are put forward:

1 South Africa should bolster productivity, production and continuous supply of accessible and affordable good quality cowpea seeds in order to continue generating foreign revenue through the surplus, which is exported. This raises a need for designing and developing an integrated mainstream seed system involving the various stakeholders, including the public-private partnerships while taking cognisance of farmer-based seed production and supply initiatives. The mainstreaming of the seed system requires investment in basic infrastructure, including proper seed storage facilities and better access roads closer to or within farming communities to ensure that farmers have access to affordable good quality seed at the right time. Furthermore, this is bound to foster farmers' access to new and improved cowpeas varieties that meet domestic and export markets demands. Other ways through which to boost the growth and development of the cowpea plant using crop production inputs, cowpea value chain and supply of good quality cowpea seeds include supporting farmers to increase hectarage under cowpeas production, as well as designing and developing user friendly policies pertaining to seed systems. In addition to increased yield through hybridization, breeding may entail biofortification and developing varieties with low or completely no anti-nutritional contents, hence increased bioavailability for iron, zinc and protein as well as reduced antinutritional factors (trypsin and phytate) increases bioavailability through biofotification technique.

2 Increase consumer awareness about the nutritional and health benefits of cowpeas and other indigenous legumes, among other socio-economic benefits. This is important in spurring cowpeas consumption domestically while countering the over reliance on animal products as protein sources and the associated risks such as overweight, obesity, cancer, blood pleasure, etc. Furthermore, through consumer awareness, the wrong perception that cowpeas and other legumes are "*poor man's food*" is bound to change. Consumer awareness may be achieved through farmer-market linkages, consumer education and promotion campaigns, business training on cowpea production technology and market linkages, among other means. Third. Invest in agro-processing or post-harvest technologies through which anti-nutrient components of cowpeas and other legumes can be reduced to minimal concentrations or completely inactivated such that they do not interfere with the digestibility. This is bound to spur the demand for cowpeas for consumption.

Future prospects

Cowpea genetic resources management, evaluation and demand-led variety selection as well as target product development are key activities that required for cowpea breeding. Cowpea is an important source of legume food crop and sources of income along the cowpea value chains. Genetic variation, germplasm acquisition, evaluation, selection and breeding population development, as well as maintenance of this genetic resource are critical components that are required to design the breeding programme of cowpea and release smallholders and commercial farmers preferred cultivars in the future. Plant based nutritional benefits and resilience of the crop performing well under adverse environmental conditions provides an opportunity for policy makers to support the research and development for large scale production of the crop compared with other major traditional legumes and cereal crops.

Declaration of Competing Interest

The authors declare that they have no conflict of interest.

References

Abstract of Agricultural Statistics. 2019. Department of Agriculture, Forestry and Fisheries (DAFF). Pretoria, South Africa.

Ajeigbe, H.A., Ekeleme, F., Chikoye, D. 2010. Improved Crop– livestock System for Enhanced Food Security and Income Generation in West Africa: Final Project Report: Gatsby Improved Crop - livestock Project. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 50p.

Akindahunsi, A.A., Salawu, S.O, 2005. Phytochemical screening and nutrient composition of selected tropical green leafy vegetables. Afr. J. Biotechnol. 4 (6), 497–501.

Akinola, R., Pereira, L.M., Mabhaudhi, T., de Bruin, F.M., Rusch, L., 2020. A Review of Indigenous Food Crops in Africa and the Implications for more Sustainable and Healthy Food Systems. Sustainability 12 (8), 3493. https://doi.org/10.3390/su12083493.

Amablc, R.A.. and J. Rugambisa. 1992. Supply, demand, and marketing channels for cowpea in southern Africa. Pages 4-11 in Cowpea technology transfer to smallholders, edited by R.A. Amabte and D.M. Naik. SADC/IITA. Maputo. Mozambique.

Asiwe, J.A.N., 2009. Needs assessment of cowpea production practices, constraints and utilization in South Africa. African Journal of Biotechnology 8 (20), 5383–5388.

Benz, B., 2012. The conservation of cultivated plants. Nat. Educ. Knowl. 3 (10), 4. https://www.nature.com/scitable/knowledge/library/the-conservation-of-cultivated-plants-80059198/.

Battersby, J., 2011. The State of Urban Food Insecurity in Cape Town; Urban Food Security Series. Queen's University and AFSUN, Kingston, ON, Canada; Cape Town, South Africa.. Online: http://www.afsun.org/wp-content/uploads/2013/09/AFSUN_11.pdf.

Claasen, N., van der Hoeven, M., Covic, N. 2016. Food environments, health and nutrition in South Africa, Working Paper 34. Cape Town: PLAAS, UWC and Centre of Excellence on Food Security. http://www.plaas.org.za/plaas-publication/wp34-foodenvironment-nc-etal.

Crush, J., Hovorka, A., Tevera, D., 2011. Food security in Southern African cities. Prog. Dev. Stud. 11, 285–305.

Rudolph, M., Kroll, F., Ruysenaar, S., Dlamini, T. 2012. The State of Food Insecurity in Johannesburg, Research Report. Available online: http://www.afsun.org/wp-content/uploads/2013/09/AFSUN_12.pdf.

Bureau for Food and Agricultural Policy (BFAP). 2019. BFAP baseline. Agricultural outlook 2019-2028. Online at: https://www.sagis.org.za/BFAPBaseline-2019.pdf

Chelang'a, P.K., Obare, G.A., Kimenju, S.C, 2013. Analysis of urban consumers' willingness to pay a premium for African Leafy Vegetables (ALVs) in Kenya: A case of Eldoret Town. Food Secur 5 (4), 591–595.

Cloete, P.C., Idsardi, E.F, 2013. Consumption of Indigenous and Traditional Food Crops: Perceptions and Realities from South Africa. Agroecol. Sustain. Food Syst. 37 (8), 902–914. https://doi.org/10.1080/21683565.2013.805179.

Davids, T., Meyer, F.H, 2017. Price formation and competitiveness of the South African broiler industry in the global context. Agrekon 56 (2), 123–138.

DAFF. 2011. Department of Agriculture, Forestry and Fisheries. 2011. Production guidelines for cowpeas. Pretoria: Directorate Agricultural Information Services. Available at http://www.daff.gov.za.

Department of Agriculture, Forestry and Fisheries (DAFF). 2016. Abstract of Agricultural Statistics. Available from: http://www.daff.gov.za/docs/statsinfo/Abstract_2012.pdf.

Delport, M., Louw, M., Davids, T., Vermeulen, H., Meyer, F., 2017. Evaluating the demand for meat in South Africa: An econometric estimation of short term demand elasticities. Agrekon 56 (1), 13–27. https://doi.org/10.1080/03031853.2017.1286249.

Drimie, S. 2016. Understanding South African Food and Agricultural Policy Implications for Agri-Food Value Chains, Regulation and Formal and Informal Livelihoods. Available online: http://www.plaas.org.za/plaas-publication/wp39-foodagripolicy-drimie.

Evans, L.T., Fischer, R.A., 1999. Yield potential: Its definition, measurement and significance. Crop Sci 39, 1544–1551.

Faber, W., 2020. Global warming and cattle production. Production 11 (2), 58–61 Online at https://www.chemunique.co.za/ruminant/global-warming-and-cattle-production/.

Gerrano, AS, Adebola, P.O., Jansen van Rensburg, W.S., Laurie, S.M., 2015. Genetic Variability in Cowpea [*Vigna unguiculata* (L.) Walp.]. Genotypes. S. Afr. J Plant Soil 32 (3), 165–174.

Gerrano, A.S., van Rensburg, W.S.J., Kutu, F.R, 2019. Agronomic evaluation and identification of potential cowpea (*Vigna unguiculata* L. Walp) genotypes in South Africa. Acta Agric Scand B Soil Plant Sci 69 (4), 295–303. https://doi.org/10.1080/09064710.2018.1562564.

Gondwe, T.M., Alamu, E.O.;, Mdziniso, P., Maziya-Dixon, B., 2019. Cowpea (Vigna unguiculata (L.) Walp) for food security: An evaluation of end-user traits of improved varieties in Swaziland. Sci. Rep. 9, 1–6.

Imamura, F., Micha, R., Khatibzadeh, S., Fahimi, S., Shi, P., Powles, J., Mozaff arian, D., 2015. Dietary quality among men and women in 187 countries in 1990 and 2010: a systematic assessment. Lancet Glob Health 3, e132–e142.

Iorlamen, T., Omoigui, L.O., Kamara, A.Y., Garba, U., Iyorkaa, N., Ademulegun, T., Solomon, R. 2021. Developing Sustainable Cowpea Seed Systems for Smallholder Farmers through Innovation Platforms in Nigeria: Experience of TL III Project. Improved Legume Varieties through Multi-Stakeholder Platforms, https://doi.org/10.1007/978-981-15-8014-7-9.

Jaichand, V., Dwarka, D., Gerrano, A.S., Mellem, J.J, 2020. Effect of heat processing on the nutritional and antinutritional factors of cowpea (Vigna unguiculata). The Annals of the University Dunarea de Jos of Galati Fascicle VI – Food Technology 44 (1), 165–177. https://doi.org/10.35219/foodtechnology.2020.1.10.

Kamara, . A.Y., Omoigui, L.O., Kamai, N., Ewansiha, S.U., Ajeigbe, H.A. 2018. Improving cultivation of cowpea in West Africa. S. Sivasankar et al. (eds.), Achieving sustainable cultivation of grain legumes, Burleigh Dodds Science Publishing, Cambridge, UK, (ISBN: 978 1 78676 140 8.

Kansiime, M.K., Ochieng, J., Kessy, R., Karanja, D., Romney, D., Afari-Sefa, V., 2018. Changing Knowledge and Perceptions of African Indigenous Vegetables: The Role of Community-Based Nutritional Outreach. Dev. Pract. 28 (4), 480–493. https://doi.org/10.1080/09614524.2018.1449814.

Kenton, W. 2020. Balance of trade (BOT). Online at: https://www.investopedia.com/terms/b/bot.asp#:~:text=Balance%20of%20trade%20(BOT)%20is,balance%20of%20payments%20(BOP).

Kouyate, Z., Dao, K.M., Togola, O., Malle,A.K., Malle, O., Diakite, K., Traore, A. 2021. Cowpea Seed Innovation Platform: A Hope for Small Seed Producers in Mali. E. Akpo et al. (eds.), Enhancing Smallholder Farmers' Access to Seed of Improved Legume Varieties through Multi-Stakeholder Platforms, https://doi.org/10.1007/978-981-15-8014-7_10.

Kroll, F., Swart, E.C., Annan, R.A., Thow, A.M., Neves, D., Apprey, C., Aduku, L.N.E., Agyapong, N.A.F., Moubarac, J.-C., Toit, A.d., Aidoo, R., Sanders, D., 2019. Mapping Obesogenic Food Environments in South Africa and Ghana: Correlations and Contradictions. Sustainability 11 (14), 3924. https://doi.org/10.3390/su11143924.

Louwaars, N.P., 2007. Seeds of confusion: the impact of policies on seed systems. Wageningen University, Wageningen.

Louwaars, N.P., de Boef, W.S., 2012. Integrated seed sector development in Africa: a conceptual framework for creating coherence between practices and policies. J. Crop Improv. 26, 39–59.

Mabhaudhi, T., Chibarabada, T.P., Chimonyo, V.G.P., Murugani, V.G., Pereira, L.M., Sobratee, N., Govender, L., Slotow, R., Modi, A.T., 2019. Mainstreaming Underutilized Indigenous and Traditional Crops into Food Systems: A South African Perspective. Sustainability 11 (1), 172. https://doi.org/10.3390/su11010172.

Mahlangu, S.A., Belete, A., Hlongwane, J.J., Luvhengo, U., Mazibuko, N., 2020. Identifying potential markets for African leafy vegetables: Case study of farming households in Limpopo Province. S. Afr. Int. J. Agron.. https://doi.org/10.1155/2020/8819295.

Mare, F.A., Bahta, Y.T., Van Niekerk, W., 2018. The impact of drought on commercial livestock farmers in South Africa. Dev. Pract. 28 (4), 884–898. https://doi.org/10.1080/09614524.2018.1493091.

Mbhenyane, X.G., 2017. Indigenous foods and their contribution to nutrient requirements. South Afr. J Clin. Nutr. 30 (4), 5–7.

Mofokeng, M.A., Gerrano, A.S, 2021. Efforts in breeding cowpea for aphid resistance: A review. Acta Agric Scand B Soil & Plant Sci. https://doi.org/10.1080/09064710.2021.1923797.

Mortimore, M.J., Singh, B.B., Harris, F., Blade, S.F. 1997. Cowpea in traditional cropping systems. In: Singh, B.B., Mohan-Raj, D.R., Dashiell, K.E., Jackai, L.E.N. (Eds.), Advances in Cowpea Research. Copublication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS) IITA, Ibadan, Nigeria, pp. 99-113.

Mtolo, M., Gerrano, A.S., Mellem, J., 2017. Effect of simulated gastrointestinal digestion on the phenolic compound content and in vitro antioxidant capacity of processed Cowpea (V. unguiculata) cultivars. *CyTA* - J. Food Sci. 15 (3), 391–399. https://doi.org/10.1080/19476337.2017.1285816.

National Department of Agriculture. 1995. South Africa Country Report. Presentation to International Conference and Programme on Plant Genetic Resources. Leipzig.

Ntombela, S., Nyhodo, B., Ngqangweni, S., Phahlane, H., Lubinga, M., 2017. Economy-wide effects of drought on South African agriculture: A computable general equilibrium (CGE) analysis. J. Dev. Agric. Econ. 9 (3), 46–56. https://doi.org/10.5897/JDAE2016.0769.

Oirere, S. 2019. Meat consumption rising in South Africa. Online at: https://www.world-grain.com/articles/12371-meat-consumption-rising-in-south-africa

Ojiewo, C.O., Rubyogo, J.C., Wesonga, J.M., Bishaw, Z., Gelalcha, S.W., Abang, M.M, 2018. Mainstreaming Efficient Legume Seed Systems in Eastern Africa: Challenges, opportunities and contributions towards improved livelihoods. Rome. Food and Agriculture Organization of the United Nations.. Online at http://www.fao.org/3/CA1826EN/ca1826en.pdf.

Omotayo, A.O., Aremu, A.O., 2020. Underutilized African indigenous fruit trees and food-nutrition security: Opportunities, challenges, and prospects. Food Energy Secur 9, e220 2020.

Pereira, L., Drimie, S., 2016. Governance Arrangements for the Future Food System: Addressing Complexity in South Africa. Environment: Environ Sci. Policy for Sustainable Dev. 58 (44), 18–31. https://doi.org/10.1080/00139157.2016.1186438.

Taruvinga, A., Nengovhela, R., 2015. Consumers' perceptions and consumption dynamics of African leafy vegetables (ALVs). Evidence from Feni Communal Area, Eastern Cape Province, South Africa. 5th Int. Conf. Biomed. Eng. Technol. 18 (1), 89–95.

Tanto, T., Tefera, E. 2003. Collection, Conservation, Characterization and Sustainable Utilization of Grain Legumes in Ethiopia. Proceedings of the Workshop on food and forage legumes, 22-26 September2003, Addis Ababa, Ethiopia. Ed. Kemal, A., Seid A., Gemechu, K., Surendra, B., Rajendra S.M., Khaled, M. published by International Center for Agricultural Research in the Dry Areas.

Tchuenchieu, A.K., Kesa, H. 2020. Promotion of indigenous foods consumption for non-communicable diseases management: A challenge for south Africa in the 4th industrial revolution context. Online at: https://www.researchgate.net/publication/346916404.

Scholtz, M.M., Scholtz, M.M., Van Ryssen, J.B.J, 2013. A South African perspective on livestock production in relation to greenhouse gases and water usage. S. Afr. J. Anim. Sci. 43 (3), 247–254.

Siddique, K.H.M., Johansen, C., Turner, N.C., Jeuffroy, M., Hashem, A., Sakar, D., Gan, Y., Alghamdi, S.S, 2012. Innovations in agronomy for food legumes. A review. Agron. Sustain. Dev. 32, 45–64.
Sidibe, A., Vodouhe, R.S., N'Danikou, S, 2015. Mali: an overview of community seed and gene banks. In: Vernooy, R, Shrestha, P, Sthapit, B (Eds.), Community Seed Banks: Origins, Evolution, and Prospects. Routledge, Abingdon, England, pp. 125–130.
Smale, M., Diakité, L., Sidibé, A., Grum, M., Jones, H., Traore, I.S., Guindo, H., 2010. The impact of participation in diversity field fora on farmer management of millet and sorghum varieties in Mali. African J. Agric. Resour. Econ. 4, 23–47.
Stats SA. 2017a. Stats biz. Statistics for business. Online at: http://www.statssa.gov.za/wp-content/uploads/2017/10/StatsBiz_October2017.pdf.
Stats SA. 2017b. Digging deeper into your pocket? These prices might be to blame. Online at: http://www.statssa.gov.za/?p=10604.
Stats SA (2017c). Falling prices: the good, the better, and the best. Online at: http://www.statssa.gov.za/?p=10585
Steinfeld, H., Wassenaar, T., Jutzi, S., 2006. Livestock production systems in developing-countries: status, drivers, trends. Rev. Sci. Tech. 25, 505–516.
Souza, E., Sorrells, M.E., 1991. Relationships among 70 American oat germplasm. I. Cluster analysis using quantitative characters. Crop Sci 31, 599–605.
Sperling, L., McGuire, S., 2010. Understanding and strengthening informal seed markets. Exp. Agric. 46, 119–136.
Spires, M., Delobelle, P., Sanders, D., Puoane, T., Hoelzel, P., Swart, R. 2016. Diet-related non-communicable diseases in South Africa: determinants and policy responses. In: Padarath, A., King, J., Mackie, E. and Casciola, J. S. Afr. Health Rev. 2016(1), 35-42. Durban: Health Systems Trust. https://hdl.handle.net/10520/EJC189320.
Unigwe, A.E., Doria, E., Adebola, P., Gerrano, A.S., Pillay, M., 2018. Anti-nutrient analysis of 30 Bambara groundnut (Vigna subterranea) accessions in South Africa. J. Crop Improv. 32 (2), 208–224. https://doi.org/10.1080/15427528.2017.1405857.
USDA FAS, United States Department of Agriculture Foreign Agricultural Service. 2015. The South African meat market.
United Nations, Department of Economic and Social Affairs, Population Division. 2017. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables. ESA/P/WP/248, New York.
United Nations. 2019. Sustainable Development Goals. Available online at https://sustainabledevelopment.un.org/sdgs.
van Etten, J., de Sousa, K., Aguilar, A., Barrios, M., Coto, A., Dell'Acqua, M., Fadda, C., Gebrehawaryat, Y., van de Gevel, J., Gupta, A., Kiros, A.Y., Madriz, B., Mathur, P., Mengistu, D.K., Mercado, L., Nurhisen, M.J., Paliwal, A., Pè, M.E., Quirós, C.F., Rosas, J.C., Sharma, N., Singh, S.S., Solanki, I.S., Steinke, J., 2019. Crop variety management for climate adaptation supported by citizen science. Proc Natl Acad Sci 116, 4194–4199.
Van Heerden, I.V., Schönfeldt, H.C., 2011. The lack of food intake data and the consequences thereof. S. Afr. J. Clin Nutr. 24 (1), 10–18.
Van Wyk, B.E., Gericke, N., 2000. People's plants: a guide to useful plants of Southern Africa. South Africa. Briza Publications.
Vorster, H.J., Stevens, J.B., Steyn, G.J, 2008. Production Systems of Traditional Leafy Vegetables: Challenges for Research and Extension. S. Afr. J. Agric. Ext. 37, 85–96.