Transitioning out of GM maize: Towards nutrition security, climate adaptation, agro-ecology and social justice

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Contents

On 7 April 2015 the African Centre for Biosafety officially changed its name to the African Centre for Biodiversity (ACB). This name change was agreed to by consultation within the ACB, to reflect the expanded scope of our work over the past few years. All ACB publications prior to this date will remain under our old name of African Centre for Biosafety and should continue to be referenced as such.

We remain committed to dismantling inequalities in the food and agriculture systems in Africa and to our belief in peoples' rights to healthy and culturally appropriate food, produced through ecologically sound and sustainable methods, and to define their own food and agriculture systems.

www.acbio.org.za
PO Box 29170, Melville 2109, Johannesburg, South Africa. Tel: +27 (0)11 486 1156

Copyeditor: Liz Sparg
Design and layout: Adam Rumball, Sharkbuoys Designs, Johannesburg
Cover Illustration: Vanessa Black

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Abbreviations

ACB	African Centre for Biodiversity
AGRA	Alliance for a Green Revolution in Africa
ARC	Agricultural Research Council
ARC-GCI	Agricultural Research Council Grain Crops Institute
BFAP	Bureau for Food and Agricultural Policy
DAFF	Department of Agriculture, Forestry and Fisheries
DSD	Department of Social Development
FST	Farming Systems Trial
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IPES-Food	International Panel of Experts on Sustainable Food Systems
GMO	Genetically Modified Organisms
NAMC	National Agricultural Marketing Council
OPV	Open Pollinated Variety
PACSA	Pietermaritzburg Agency for Community Social Action
SADC	Southern African Development Community
WEMA	Water Efficient Maize for Africa
YoY	year-on-year

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About this paper

This paper forms part of a greater voice in South Africa and globally that is calling for the urgent transformation of agro-food systems that are inequitable, ecologically unsustainable, nutritionally deficient and hazardous for farm workers, towards agroecology and food sovereignty (such as IPES-Food, the UN, Oxfam, WWF, La Via Campesina, Friends of the Earth, IAASTD, amongst many other state and non-state actors).

The current agricultural system is deeply fragile and requires an urgent shift away from the focus on a maize monoculture towards embracing a diversity of crops – particularly indigenous African summer grain crops – and diverse agricultural practices that support healthy ecosystems, economies and societies.

The recent drought crisis in South Africa presents us with an opportunity to interrogate the current over-reliance on genetically modified (GM) maize production to provide staple food for millions of South Africans and fodder for the animal feed sector. This paper examines the link between agricultural and dietary diversification, by looking at the complex agriculture and food systems that create nutritionally deficient soils and people, and that cannot be corrected by technological, quick-fix solutions.

It is time to develop a food system that supports both producers and consumers, instead of one that creates and perpetuates risk and vulnerability, where only the strongest and most competitively advantaged survive. We need to shift away from simply increasing production through high-yielding, high-calorie staple crops, towards improving food quality and nutritional content; and to address the structural and systemic issues that create persistent poverty, inequality and unemployment – the root causes of hunger and malnutrition in South Africa.

Key findings

The prolonged drought being experienced in South Africa due to the El Niño phenomenon hit summer crop production areas the hardest, particularly the white maize production areas. This has impacted on food availability and affordability; in order to meet local demand, an unprecedented amount of white and yellow maize has been imported.

White maize yields dropped from 14.2 million tonnes in 2014, to 9.6 million tonnes in 2015, to 7.16 million tonnes in 2016. The latter maize crop is the smallest harvested since the 2006/7 production season. Irrigated maize cultivation performed the best under the harsh conditions, but makes up only 20% of maize cultivation.

By the end of June 2016, 1 million tonnes of white maize had been imported, compared to 102,179 tonnes in 2015 and no imports in 2014. By the same date, 2.3 million tonnes of yellow maize had been imported, compared to the 1,866,340 tonnes in 2015 and 65,250 tonnes in 2014. It is expected that South Africa will import 5 million tonnes of maize between May 2016 and April 2017.

White maize represents a small share of global maize production, and has limited production areas. White maize imports (non-GM) have come to South Africa from Mexico and the United States. Zambia also produces white maize, but in April 2016 suspended the export of grain to prevent local shortages. Yellow maize is produced more widely, with imports coming primarily from Brazil and Argentina (both GM). With limited option for white maize imports, it will be important to monitor whether GM maize from the United States will be given commodity clearance by South Africa's biosafety authorities, due to the local and regional demand.

The current drought is providing impetus for seed companies to promote both hybrid and drought tolerant GM maize varieties, through the Water Efficient Maize for Africa (WEMA) project. Monsanto's drought tolerant GM maize, MON87460 has been given commercial clearance despite it not being up to the task of providing a solution to the complex physiology of drought tolerance. Nevertheless, despite widepread opposition and proof of negligible yield increases, this GM maize is further being stacked with Bacillus thuringiensis (Bt), which is toxic to insects, and herbicide tolerant traits for field trials.

Two hybrid varieties of Drought*TEGO*™, WE3127 and WE3128 have been registered with the Department of Agriculture, Forestry and Fisheries (DAFF) for commercial sale. WE3128 will be available in late 2016, and is primarily intended for smallholder farmers in South Africa, who will not have to pay royalties.

Reduced yields, increased imports, and a depreciating rand have had implications for both producers and consumers. Low yields pose a huge risk for commercial maize farmers and farming debt levels have already reached record highs. Commercial farmers are beginning to shift towards conservation agriculture and, in some cases, from GM seed to hybrid and open pollinated varieties (OPVs), in order to reduce input costs and increase profitability. OPVs might have a lower yield, but are much cheaper than hybrid/GM maize varieties.

From an agronomic perspective, conservation agriculture may have the potential to be an intermediate step to transition out of monocrop GM maize production. Regrettably, however, current crop rotations are really "glorified monocultures" with farmers rotating between GM soya and GM maize, and in the western parts of the country rotating between GM maize and sunflower.

The drought and the weakening exchange rate have also hit consumers hard. The August Pietermaritzburg Agency for Community Social Action (PACSA) reported that 25kg of maize meal has been subjected to a 39.6% year-on-year (YoY) increase, while the National Agricultural Marketing Council's (NAMC) food price monitoring report suggests that 5kg of maize meal has increased as much as 43.7% between January 2015 and January 2016. Increased grain prices have implications for other value chains, most notably animal production and the costs of poultry and beef. Food price inflation is particularly impactful on low-income consumers.

The South African population prefers consuming white maize, while yellow maize is preferred for animal feed, due to its natural carotene; however, when there is a shortage, white maize may be used as a substitute. To prevent this happening, the price of white maize is raised, impacting on low-income consumers who rely on white maize as a staple food.

Despite South Africa's ability to produce and procure sufficient quantities of food, about 46% of households goes hungry. Simply increasing production and using technological tools, such as GM seed does not address food and nutritional insecurity. Deeper systemic inequalities within our entire food system must be addressed.

With climate change creating shifting bio-climatic and agroecological zones, maize will become less suitable as a staple food, particularly in the western, drier parts of the country. The current adaptive strategy of using irrigation to maintain staple food production will not be an option with increasing water scarcity.

Despite the rhetoric to identify and support more and diverse drought tolerant crops, maize receives the lion's share of investment into varietal research and development. There is minimal support for public breeding programmes of sorghum or other crops that will increase both agricultural biodiversity and nutrition security. At Grain SA some research is taking place on sorghum, but due to the limited market, this is not a priority. Millet is not a crop that either Grain SA or the Agricultural Research Council Grain Crops Institute (ARC-GCI) appears to be interested in. These are clearly missed opportunities. There is an urgent need to map future agroecological zones and identify crop suitability, keeping in mind indigenous summer crops (for example, sorghum and millet).

Currently all new cultivars are tested in monocropped systems, with the use of other external inputs, such as synthetic fertilisers and pesticides. New indicators beyond yield, profitability and calorie content must be developed to best understand the performance of cultivars, and broadened to take into account other factors, including nutritional value and performance under diversified agroecological farming practices.

Research and development and the revival of indigenous grain crops needs to be coupled with product development and marketing campaigns to revive interest in the use and consumption of indigenous foods, which tend to be viewed negatively, while highly processed foods are aggressively marketed as prestige foods and viewed as such by many consumers.

The moves by retail giant Woolworths to marketing non-GMO maize meal, and by SA Rice Mills, a family-owned business, to establishing a non-GMO maize milling facility, are examples of slow paradigm shifts taking place in the South African maize sector.

There is evidence that drought tolerant and resilient food systems are best achieved by supporting agroecology, agrobiodiversity and seed sovereignty, and preventing the expropriation and exploitation of thousands of years of co-evolution and knowledge sharing. These findings provide compelling evidence why we must urgently transition out of the current system towards an ecologically sustainable and socially just food system.

A deficient food system

The hegemonic discourse, emanating from proponents of the Green Revolution in Africa, such as the Alliance for a Green Revolution in Africa (AGRA) argues that in order to "feed the world" more food needs to be produced, and therefore, the focus is the use of advanced and intensive agricultural techniques that produce high-yielding crops and rely on high agrochemical input. Yet this argument justifies a flawed system whose policies and practices exacerbate the conditions of hunger and undermine our ability to feed future generations (Cook et al., 2016).

The tendency to use technological fixes to solve the deficiencies in the current global food system, such as transgenic techniques for insect resistant and herbicide tolerant crops that rely on high agrochemical input, ready-to-use therapeutic foods, fortification and bio-fortification, have left soils and societies nutritionally deficient and lacking in resilience. This overlooks the need to bring about systemic changes, in order to address the root causes of unemployment and inequality, which are shown to be the main contributing factors to nutritional insecurity, rather than a lack of food availability in South Africa and elsewhere in the world. Product-based "solutions" offer new pathways for profit-making and the sale of commodities, such as certified seed, processed products, agrochemicals, fortification mixtures, etc., and neglect the right to safe and nutritious foods.

It is generally accepted that industrialised agriculture, which has been able to produce food on a large scale, has not curbed the widespread food and nutritional insecurity globally, including in South Africa. The industrial model of agriculture, embedded within inequitable and environmentally destructive global commodity trade systems, prevents meaningful transformation towards sustainable land and resource use and agroecological food production. Agroecological systems can simultaneously address the climate, ecological and social injustice crises that beset the current food system. The link between diet, nutrition and agriculture is clear and captured in the Sustainable Development Goal (SDG) 2, which aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture (United Nations General Assembly, 2014). South Africa's position is based on the National Development Plan, which is aligned with the SGDs, but focuses primarily on creating jobs and reducing poverty and inequality (Kosciulek, 2015; DEA, 2016).

South Africa is experiencing rapid resource depletion, and simultaneously, the country is wracked by a "double burden", where there is both severe undernutrition and overweight and obesity, due to the reliance on cheap, over-processed, single food diets. We urgently need alternative pathways to supporting and strengthening agricultural biodiversity and dietary diversity, in order to sustain an increasing and urbanising population.

The current agro-food system is having a depletive effect on both the soils and nutrition. New food systems approaches are required that consider the life-cycle of produce from farm to plate, including production, processing, distribution, food environments, diets, and health and nutrition. From both agricultural and nutritional perspectives, technological fixes are not suitable to address the deeper systemic issues causing inequalities that allow 46% of households to go hungry.

Staple food as a commodity

Post-1994, with the advent of South Africa's economic liberalisation and the removal of agricultural subsidies, the market began to determine food production, availability and pricing (DAFF, 2011). Local food producers became dependent on import tariffs for protection. An unregulated market environment left the domestic agricultural sector vulnerable to fluctuating global prices of staple foods, while consolidation of production, agro-processing and retail sectors decreased the market entry points for new agricultural producers. Coupled with increasing input costs, poor infrastructural support, unsustainable agricultural practices, reduced productivity, and poor information and resource management, this has led to a highly vulnerable food situation, where only the most robust agribusinesses are able to survive.

The volatility in the global food commodity trading system has impacted on the production and affordability of food. In years of maize surpluses, the price of maize plummets, with many farmers in danger of bankruptcy. In times of shortages, many farmers become indebted due to limited yields. For South Africa, as a net importer of agricultural inputs, such as fuel and fertiliser, the exchange rate has dire implications for the domestic cost of inputs and the price of production, even when crude oil price is low – with negative impacts downstream on food prices (BFAP, 2016) and the livelihoods of the poor. In the 2015/16 production year, due to the prolonged drought and years of reduced yields, many commercial farmers face financial crises, resulting in a further consolidation of the sector into a smaller group of well-resourced farmers and agribusinesses.

The commodification of all aspects of the agro-food system in South Africa has allowed for high levels of concentration and vertical integration by a few major companies, and the entrenchment of anti-competitive behaviour, a huge issue affecting food price inflation (Ngidi, 2015). Just two companies dominate the domestic seed market – Monsanto and Pioneer Hi-Bred. Three firms dominate the white maize milling sector (Tiger Brands, Premier Foods, and Pioneer Foods), milling approximately 60% of South Africa's white maize, with their GM brands, Ace, White Star and Iwisa super maize meal capturing up to 73% of the maize meal market (ACB, 2013). The food retail market is equally concentrated, with just four dominant super retailers: Shoprite/Checkers, Pick n Pay, Spar and Woolworths (ACB, 2013).

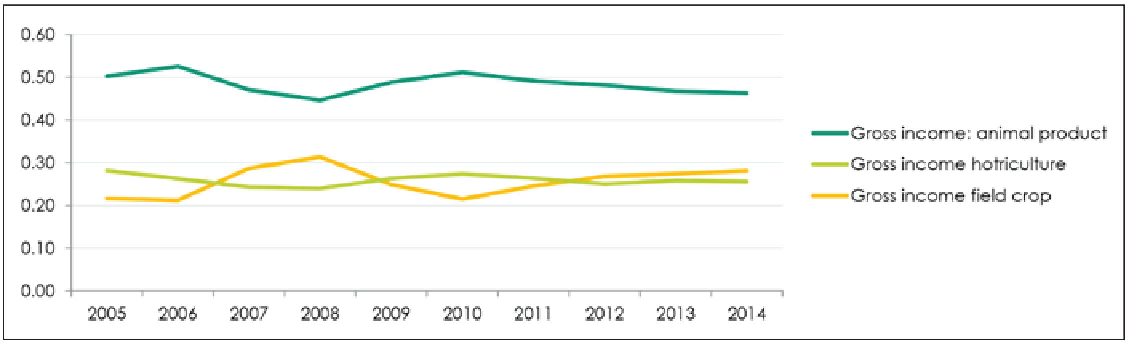
The high concentration of actors across the food value chain in South Africa exacerbates the financial risk and vulnerability for both producers and consumers, and large-scale corporations seem to be the main beneficiaries of a skewed, highly competitive industrial food structure.

Industrial agriculture and maize production in South Africa

South African agriculture is dualistic, with entrenched historical inequalities (DAFF, 2011). On the one side, there is a concentrated commercial agriculture sector, made up of less than 40,000 farming units, covering an area of approximately 82 million hectares, and responsible for 99% of marketed agricultural outputs (DAFF, 2011). Although the number of farming units has declined between 1993 and 2007 – from about 60,000 to 40,000 – outputs in this sector have continued to grow (Stats SA, 2007).

On the other side, the marginal smallholder agricultural sector consists of 1.3 million farming households, covering an estimated 14 million hectares of more marginal agricultural land, often lacking water and infrastructural

Figure 1: Contribution of the different agricultural sectors to gross income from production



Source: DAFF, 2015

resources. There are also a significant number of subsistence agricultural farmers, with little data available for this sector (DAFF, 2011).

Agriculture can be separated into three main subsectors, namely: animal production, horticulture, and field crops. In South Africa, animal production contributes the largest share of total income generated in the sector (see Figure 1). Of the three sectors, field crop production is the most volatile and dependent on weather conditions, due to the greater share being dry-land production (BFAP, 2016).

The area under maize cultivation has decreased over the last 20 years, yet production has remained relatively constant due to intensification. *Zea mays* (maize) is the world's most widely cultivated crop, and in South Africa is primarily cultivated in the Highveld region, which includes Gauteng, the Free State, parts of the Northern Cape, Mpumalanga, North West and Limpopo (Matji, 2015). Maize is the main cereal crop produced in South Africa, and is also an important input into livestock production (Dlamini, 2014). Most maize is cultivated through rain-fed agriculture, with only 20% grown under irrigation (ARC-LNR, 2015). Maize cultivated in South Africa is almost completely GM (see *Genetic modification, biosafety concerns and ecological unsustainability*, below).

Maize accounts for more than 40% of the total harvested area in South Africa. About half of South Africa's maize is used for animal feed, and about 70% of the feed is used for poultry production (WWF, date unknown). Grain production is a central input in animal production, and therefore, changes in grain production and grain pricing will have significant implications for animal production and the cost of poultry and beef (ACB, 2015b). South Africa is the continent's largest maize producer, averaging around 12 million tons per annum (ACB, 2013), with the rest of the Southern African Development Community (SADC) region depending on South Africa for 40% of its maize (Steyn, 2016).

Despite increased yields, the price of maize has increased substantially, as input costs, weak currencies, volatile commodity markets, and environmental degradation have made it difficult for both the producer and consumer to have livelihood, food and nutritional security. The impacts on food prices and consumer are discussed later in the paper.

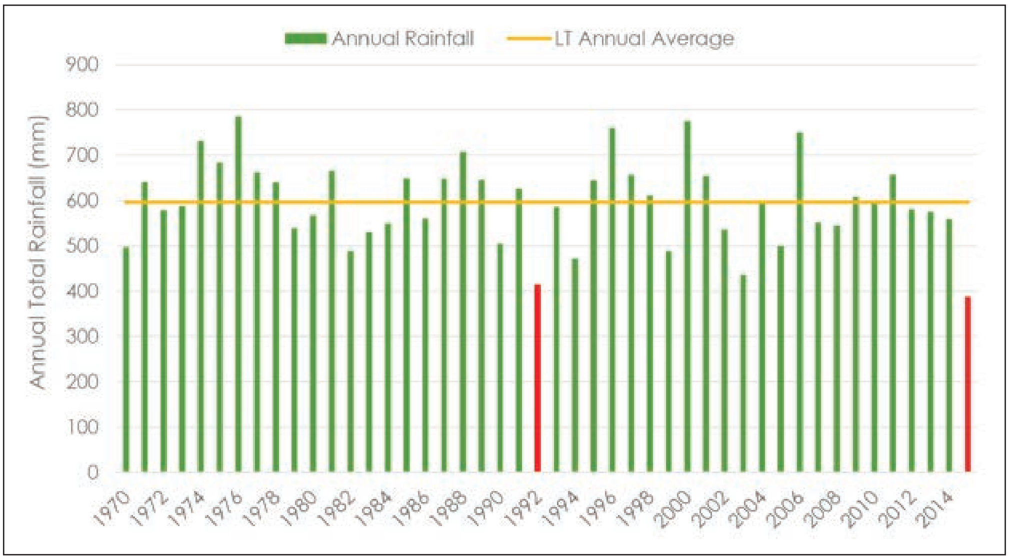
Drought and resilience (2015/16) – moving into a hotter and drier future

Due to the El Niño phenomenon, South Africa has recently seen the worst drought in its recorded history, with 2015 being the lowest national annual rainfall recorded in South Africa since 1904 (BFAP, 2016). Figure 2 illustrates rainfall levels, and contextualises the 2015/16 drought against the severe drought experienced in 1992.

The severity of the drought was especially felt in key summer crop production regions, with five provinces being declared as disaster areas as a result of the drought (BFAP, 2016).

The drought and weakening of the South African currency have had ripple effects along the entire agro-food system, ultimately with both producers and consumers bearing the brunt. The influence of El Niño on summer rainfall in the Highveld region of South

Figure 2: South Africa's annual rainfall 1970–2015



Source: BFAP, 2016

Africa has affected local food production and food security in the short term and farmers' economic security in the long term. It is expected that the 2016/17 market year will be a La Niña year in South Africa, which is associated with higher rainfall. These changes, together with the nature of the commodity market, affect farmer decisions, food availability and prices.

With the advent of climate change, large parts of the continent are expected to become hotter and drier, which will have a significant impact on maize production, as well as other crops. The shifting bio-climatic zones will impact on crop suitability, as climatic variations can alter crop productivity, timing of farming operations, and pest vigour (Midgley *et al*., 2007). There is general agreement that maize production will decline with decreasing rainfall and increasing temperatures and rainfall variability, even with the carbon dioxide fertilisation effect (Turpie et al., 2002; Akpalu *et al*., 2009; Dube *et al.*, 2013).

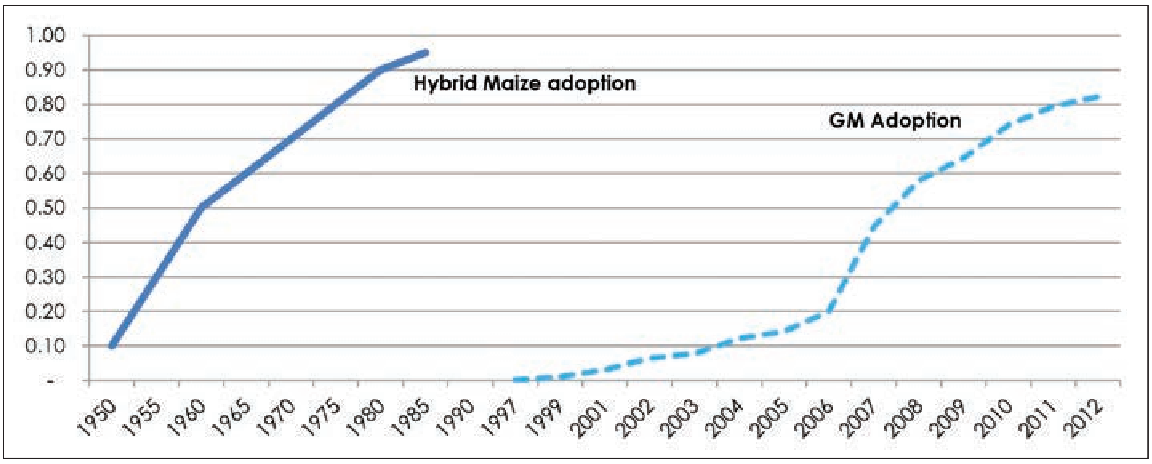
As the shifting bio-climatic zones change the ecosystems, much of the Highveld region will lose its suitability to produce maize, potentially threatening the stability of our staple food supply. This is a real concern for South Africa, as well for neighbouring states that depend on South African maize imports. The Eastern Cape Province shows suitability for maize under varying climate change scenarios (Matji, 2015). However, this raises other concerns that an expansion of maize production in the Eastern Cape will severely threaten protected areas and biodiversity (Bradley *et al*., 2012).

Although only 10% of farms are under irrigation, currently agriculture is the single largest consumer of water in the country, consuming 60% of water resources (Benhin, 2006; Blignaut et al., 2009). With increasing temperatures and less reliable rainfall, there will be a greater need for farmers to irrigate, especially in the drier western parts of the country, placing more pressure on the country's already scarce water resources. There is little possibility to expand irrigation, due to the limited supply of fresh water, which will reduce over time. This means water-saving and efficient water-use farming techniques are required, which will drive up production costs even further (Blignaut *et al*., 2009).

Genetic modification, biosafety concerns and ecological unsustainability

In 1997, South Africa became the first country in Africa to allow the cultivation of GM maize and today still remains the only country on the continent to have done so. Today, the South African maize sector is completely dominated by GM maize, accounting for over 80% of white maize planted in South Africa (ACB, 2013). South Africa is the only country in the world to allow genetic modification of its staple crop, maize, for commercial cultivation. It is debatable what

Figure 3: Adoption rates of maize in South Africa 1950–2012



Source: Dlamini, 2014

positive impact there has been, if any, of the increased adoption of GM crops on economic development, food security, and hunger (ACB, 2012). Despite longer than a decade of GM maize use in the country, food insecurity is rife, with over 46% of South African households experiencing hunger.

The current drought is providing impetus for seed companies to promote both hybrid and drought tolerant GM maize varieties, through the WEMA project.

GM drought tolerant maize, MON87460, or "Droughtgard" as it is known commercially, was approved in the United States in late 2011. According to a Monsanto submission, MON87460 reduces yield loss under water-limited conditions, but like conventional maize it is also subject to yield loss (ACB, 2015). It is also suggested that MON87460 is unlikely to have any benefit under extreme conditions (Gurian-Sherman, 2012). In the United States, where MON87460 has been introduced in drought prone maize growing areas, it is estimated that it will increase productivity by 1%, roughly the same as annual maize productivity increases resulting from conventional breeding for drought tolerance (Gurian-Sherman, 2012). With these minimal yield increases, the decision by the South African Biosafety authorities to grant approval for the commercial growing of MON87460 is highly questionable. A spate of field trials involving stacked varieties with the drought tolerant trait is highly likely to go ahead in South Africa in the near future, despite widespread objections.[1]

ARC has registered two Drought*TEGO*™ hybrid varieties, WE3127 and WE3128 with DAFF. These are high yielding under moderate drought conditions, with early-to-medium maturity (ARC-LNR, 2015a). According to ARC, both varieties were meant to be available at Jermart Seeds and Capstone in 2015, but at the time of writing they were still awaiting the seed. Jermart Seeds said WE3128 will become available in late 2016, and is primarily intended for smallholder farmers in South Africa, who will not have to pay royalties. According to the Director of Jermart Seeds, the purpose of developing these varieties is to encourage the use of hybrids by smallholder farmers,

1. The ACB has objected to these trials for a number of reasons including: confidential business information obstructs meaningful assessments; GM drought tolerant maize is an inappropriate technological fix to a systemic problem; best biosafety practices are ignored; controversies regarding the already approved parental lines have not been taken into account, for e.g. the failure of MON810 and the use of glyphosate, which has been categorised by WHO as a probable carcinogen to humans; questionable safety data has been presented by Monsanto; and the dossiers submitted by Monsanto in the application for the trials did not provide sufficient evidence to demonstrate safety (ACB, 2015) . These objections were supported by more than 25,000 signatories.

where previously only large-scale commercial farmers had access.[2] However, concerns arise around sustainability – the additional costs of purchasing seed each year, the inability to save seeds of these varieties for the purposes of replanting, and other social costs that may emerge from the use by smallholder farmers of hybrid seed.

Previously Pioneer Hi-Bred had promoted transgenic rootworm resistant maize as drought tolerant. These were developed to be resistant to particular pests that reduce water uptake due to damaged roots, but these will have no impact in South Africa as these pests are not present in the country[3] (ACB, 2015c).

South Africa has regulations and guidelines regarding GM imports, in terms of which GM commodities (GM wholegrain for example) for food, feed and processing is not allowed if the GMO in question has not yet been approved in South Africa for commercial growing. This asynchronous approval system has been developed primarily to protect local farmers who do not have access to those varieties, rather than due to biosafety considerations. This system has prevented GM maize imports from countries like the United States, which grow many more GM maize varieties than does South Africa. In 2011, 23 new GM varieties were granted commodity clearance (ACB, 2012). In the 2016/17 marketing season, three shipments have come into SA, one from the United States (non-GMO) and two from Mexico. GM seed has been imported from the United States for planting purposes (DAFF, 2016a). As of July 2016, there has been no approval of GM maize grain from the United States.[4]

Agriculture, dietary diversity, health and nutrition

South Africa experiences the "double burden", where a major proportion of society suffers from malnutrition in the forms of both undernutrition, and overweight and obesity. One in five children in South Africa are stunted, and over 50% of South African women are overweight and obese (Hawkes, 2016).

The assumption is that hunger is caused by a lack of food availability, and therefore the solution is to produce more food, hence the focus on high-yielding crop varieties. Higher-yielding crops, as part of a larger industrialised agricultural system, have not automatically translated into improved diet quality, which is the root of South African malnutrition (Hawkes, 2016). The problem of food insecurity in South Africa does not lie with food production but with unemployment and inequality (Du Toit, 2016). There needs to be a shift away from focusing on high-yielding crops with high calorie content, to a diverse range of foods that are accessible, affordable, produced in ecologically sustainable ways and are culturally appropriate. This requires a holistic approach to our food systems; one that also looks at ways to increase diet quality, and considers the impact of a product's life-cycle on nutrition and the role that well-resourced marketing campaigns and food environments play in defining consumer choice and behaviour.

Processed foods are often advertised as prestige foods, associated with wealthier strata in society, and falsely regarded as more nutritious than local foods. Wealthier parts of the population tend to have access to more diverse foods, and are not dependent on single, staple crops in the same way as poorer economic groups (FAO, date unknown). Traditional foods, which are neglected in modern South African diets can play a key transforming role, if they can be promoted appropriately within a context of consumer education and empowerment. There is currently no monitoring of consumer food environments and quality of food taking place in South Africa (Swinburn, 2016), and this is an area that requires further urgent attention.

Narrow, quick-fix, technological solutions of supplementation and/or fortification have been the main strategies to deal with nutrition

2. Abel Masekoameng, Jermart Seeds, email communication, 11 August 2016
3. Wessel Lemmer, Senior Agricultural Economist, ABSA Agribusiness, 8 July 2016
4. Corné Louw, Senior Economist, Grain SA, 19 July 2016

Table 1: Fortification standards – maize meal

		Maize Meal			
Micronutrient	**Unit**	**Super**	**Special**	**Sifted**	**Unsifted**
Vitamin A	µRE/kg *	1877	1877	1877	1877
Thiamine	mg/kg	3.09	3.86	4.76	5.57
Riboflavin	mg/kg	1.79	1.88	1.97	2.06
Niacin	mg/kg	29.7	31.86	34.65	38.25
Pyridoxine	mg/kg	3.89	4.25	4.79	5.42
Folic acid	mg/kg	1.89	1.90	1.92	1.94
Iron	mg/kg	37.35	40.14	44.28	50.40**
Zinc	mg/kg	18.90	22.55	26.60	30.20

* Retinol equivalents (RE) = 1µg = 3.33IU (International units) vitamin A
**Where special permission was granted interms of regulation 10, a lower iron content of 34.65mg/kg is allowed

Source: Department of Health, 2005

deficiencies in diets, rather than addressing systems that create malnutrition and empowering people to make better decisions around diet, nutrition and health.

In South Africa, it is required to fortify all maize and wheat imported, manufactured and sold within the required fortification mixture regulations (Department of Health, 2005). To date, the effectiveness is unknown, but evidence indicates that the levels of micronutrients added are too low to have any significant impact (Yusufali *et al*., 2012.; Lopez Villar, 2015).

Despite the call for fortification to be used only when dietary diversity cannot be attained, in a food secure country, such as South Africa, this option is still chosen over providing access to safe, nutritious, and diverse foods.

The National Policy on Food and Nutrition Security addresses the issue of food and nutritional insecurity in South Africa, and particularly that of effective risk management, improving nutritional safety nets and nutritional education as key to strengthening food and nutritional security (DSD and DAFF, 2013). Although the policy refers to the rife inequities within the agricultural and food system that perpetuate hunger and undernourishment in South Africa, it is weak in terms of providing guidance on how to transform this system. One possibility may be to use multiple pieces of existing legislation to leverage programmes geared towards supporting real transformation in the production, processing, and retail sectors (both formal and informal) and linking the Departments of Agricultural, Health, Social Development and Trade and Industry into more coherency, as has been done in other countries, such as Brazil, where combatting malnutrition has had a measure of success.[5]

The economics driving the food system

The South African maze

A variety of social, psychological, physiological, cultural and economic factors determine the choices people make about what food to eat. In an increasing urbanising society, the nutrition transition is clear and distinct, with high starch diets, sugar, fat and salt being preferred, resulting in a variety of nutritional deficiencies in South African rural and urban populations (Greenberg, 2016). The role of marketing and

5. In Brazil the rate of child malnutrition has reduced drastically, due to the holistic model adopted that considers diet to be interrelated with agriculture, food and health access, and education. This model is reiterated in the recent Dietary Guidelines for the Brazilian Population, 2014.

Figure 4a: Commercial maize production 2011–2016

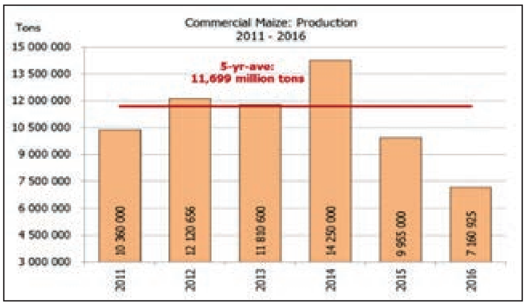


Figure 4b: Commercial white maize production 2011–2016

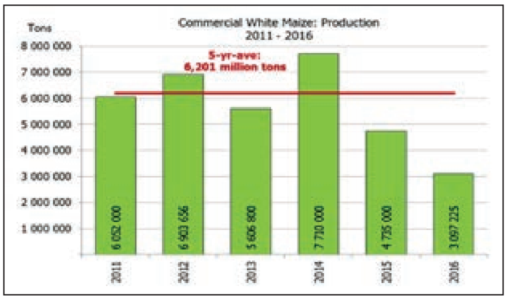
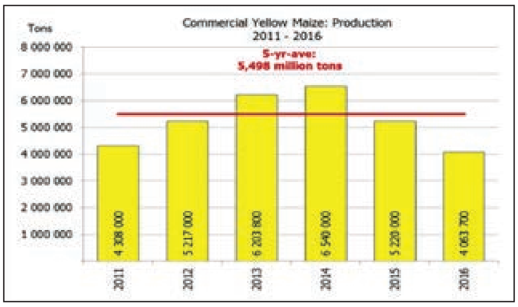


Figure 4c: Commercial yellow maize production 2011–2016



Source: DAFF, 2016

advertising is central to defining urban food behaviours, and altering consumer perceptions, often towards poorer nutritional decisions.

For much of the South African population, white maize (the whiter the better) is associated with high income status. Yellow maize is regarded as a poor man's food, or eaten in rural areas, and is associated with animal feed. In previous years, when there was insufficient white maize, yellow maize was used as a substitute by large maize meal brands. Customers broke bags in stores to see whether the maize inside was yellow or white, resulting in high wastage. Many companies changed their branding, as consumers would not buy their brands any longer.[6]

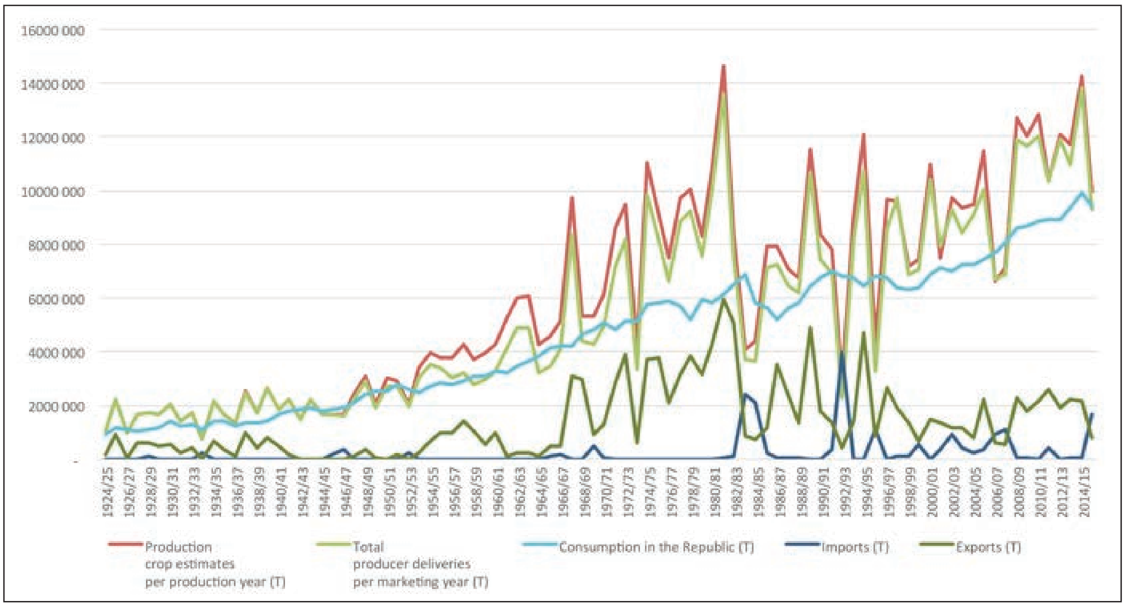
The impact of the drought on supply

South Africa is generally considered a net exporter of maize, but in 2016 became a net importer of maize – for the first time in 11 years (ARC-LNR, 2015). The drought also had a negative impact on other crops, including sunflower, dry beans, groundnuts and sorghum. The effect has been worsened due to a series of dry years in the main maize production areas of the North West and Free State, with yields dropping from 14.25 million tonnes in 2014, to 9.655 million tonnes in 2015, to 7.16 million tonnes in 2016. This is 28.1% less than in 2015, and 38.8% less than the five-year average production. The current maize crop is the smallest harvested since the 2006/7 production season (7.125 million tonnes) (DAFF, 2016). Much of the 2015/16 crop was planted in January 2016, late into the optimal planting window, due to dry conditions.

The 2015/16 drought, coupled with a depreciating rand has ramifications for the import and export parity price band, and impacts on every stage of the maize food value chain (BFAP, 2016). Internally maize trades at export parity, although Petru Fourie from Grain SA explains it is not really profitable to produce at that level and that, "Farmers are subsidising the low maize cost to the consumer."[7] In times of shortages, prices shift towards import parity,

6. Dr Hendrik Smith, National Conservation Agriculture Facilitator, Grain SA, 19 July 2016
7. Petru Fourie, Agricultural Economist, Grain SA, 19 July 2016

Figure 5: Producer deliveries, consumption, imports and exports of maize (1924/25–2015/16 marketing seasons)



Source: Data source: SAGIS, 2016

that is, higher prices for consumers, which is the case currently. Other countries in the SADC that are net importers are permanently on import parity price plus.[8]

South Africa alone needs about 10 million tonnes of maize a year for local markets, and Botswana, Namibia, Lesotho and Swaziland together need another 630,000 tonnes (Steyn, 2016).

It is expected that the majority of the maize crop will be harvested in Mpumalanga (29.7%), followed by the Free State (28.6%) and then North West (13.6%). This is the first time since 1992 that Mpumalanga will produce more maize than the Free State. The white maize growing areas have been the worst affected by the drought (Steyn, 2016). Although only 20% of maize is cultivated under irrigation, it makes a significant contribution to supply, particularly in times of drought, due to production being more stable.[9]

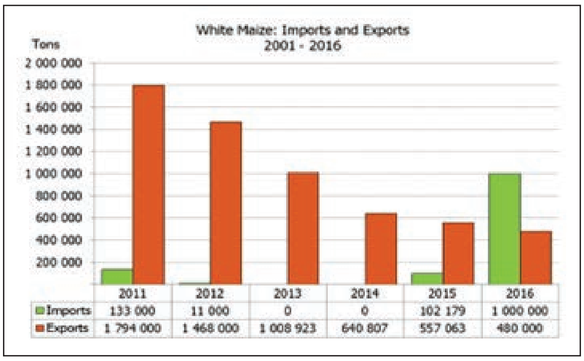
There is no information that we know of regarding varied responses/performance of different maize cultivars available on the market for analysis in the current drought period. There is very limited information on the production of OPVs on commercial scales, with only a few farmers choosing non-GM maize for a specialised market.

NAMC's National Supply and Demand Committee was established in 2012 to monitor imports and exports and local stocks, in order to make the sector more transparent. Due to reduced domestic production, maize has had to be imported to meet local demand. It is estimated that South Africa will need to import 5 million tonnes of maize between May 2016 and April 2017, as farmers planted only 1.3 million hectares of maize this season – half of the usual 2.6 million hectares (Steyn, 2016). Since South Africa is normally an exporter of maize, the total import volumes for 2016 are unprecedented.

White maize represents a small share of global maize production, and therefore limits sources of imports. Due to the preference for white maize by the South African population, there is a premium for white maize over yellow maize. Yellow maize is produced worldwide, and is cheaper and easier to obtain. However, globally yellow maize is of a lower grade, as it is grown

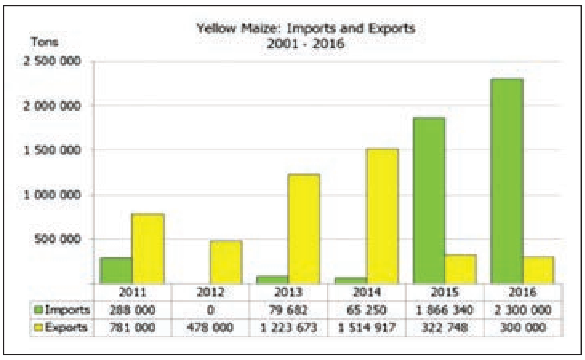
8. Corné Louw, Senior Economist, Grain SA, 19 July 2016
9. Corné Louw, Senior Economist, Grain SA, 19 July 2016

Figure 6a: Import and export of white maize 2001–2016



Source: DAFF, 2016

Figure 6b: Import and export of yellow maize 2001–2016



in wetter climates, and due to the natural carotene, is often used for livestock feed. In times of shortages white maize can also be purchased for feed (with carotene often added to the mix). To prevent this in South Africa, the price of white maize is raised.

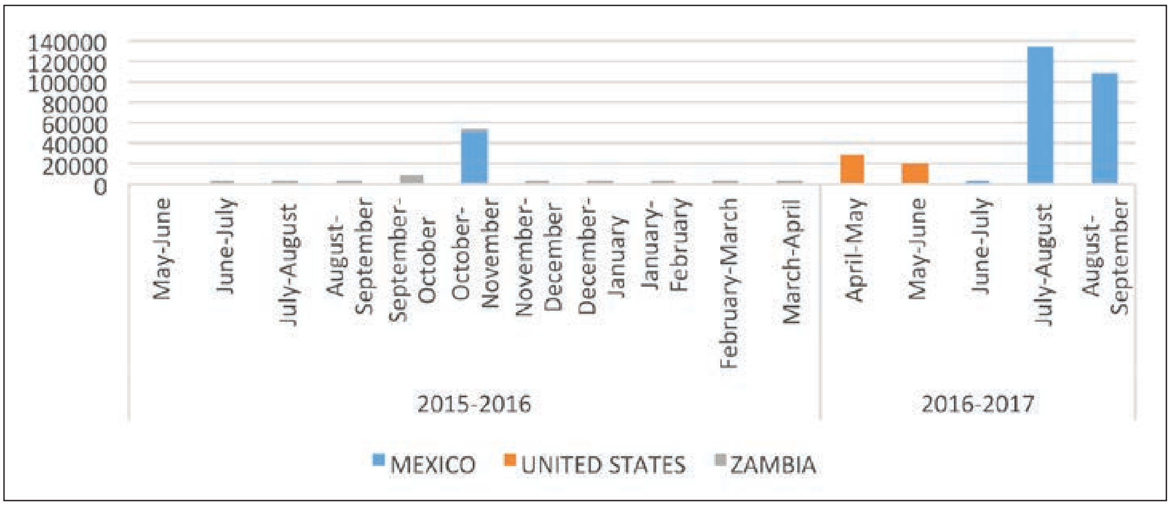
Due to the drier South African climate, both our yellow and white maize are of high quality, and are preferred by the South African millers.[10] South African millers mill 10–15% less imported maize compared to local maize.[11]

Due to the high import volumes required to meet local demand, prices will remain near import parity levels, depending on the origin of imports and the exchange rate (BFAP, 2016). White maize (non-GM) from Mexico is trading at approximately $245 Freight on Board (FOB), compared to yellow maize from Argentina (GM) at $170 FOB. Zambia also grows white maize, but in April 2016 suspended the export of grain to prevent local shortages (Fin24, 2016).

Production costs

The three largest production costs for maize farmers are fertiliser, fuel and seed (for farmers planting GM herbicide tolerant maize, herbicides are also a significant cost). Reduced

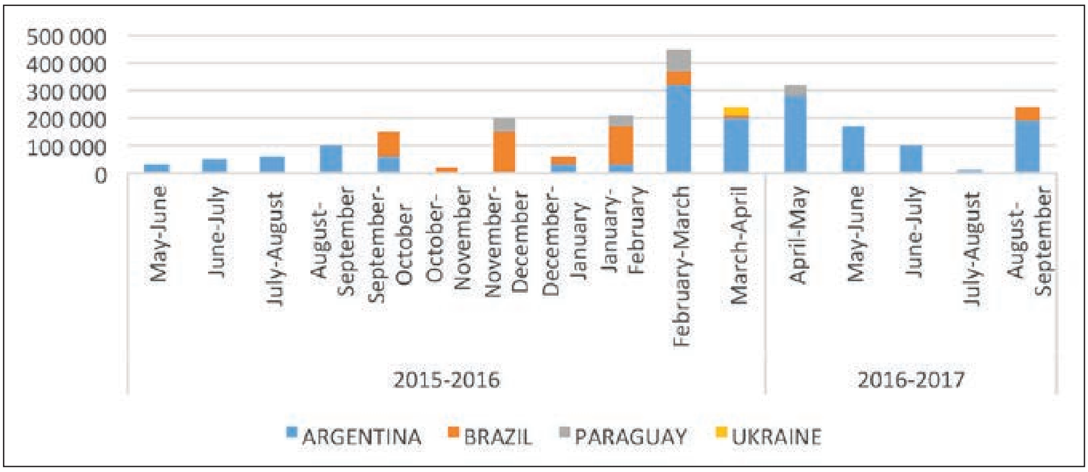
Figure 7a: Countries and quantities of white maize imported into South Africa, 2015–2017 production years



Data source: SAGIS, 2016

10. Corné Louw, Senior Economist, Grain SA, 19 July 2016
11. Wessel Lemmer, Senior Agricultural Economist, ABSA Agribusiness, 8 July 2016

Figure 7b: Countries and quantities of yellow maize imported into South Africa, 2015–2017 production years



Data source: SAGIS, 2016

yields are a huge risk for a commercial maize farmer, with farming debt levels reaching record highs. Increased costs of production and processing, due to changing fuel prices, electricity costs and the rand-dollar exchange rates all impact on food prices. Production costs should be less during dry periods, as fewer inputs are required: less top-dressing fertiliser, pesticides and herbicides, and plants do not need fungicide, due to the dry conditions.[12]

Seed makes up about 10–12% of production costs.[13] The prices of different varieties vary considerably. For example, GM maize is sold at double the price of popular hybrids, and five times the price of popular OPVs (Fischer *et al.*, 2015). The average price of stacked GM maize seed on the market was around 42% higher than single trait GM maize. In 2008, just over 5% of the maize planted in South Africa was stacked. By 2010/11 this had increased eight-fold, to 41% (ACB, 2012). Due the urgent need to reduce production costs, there is a trend to shift from GM and hybrid seed to OPVs.

For the few farmers who had a harvest despite these harsh conditions, the higher prices are beneficial. But many farmers will incur further debt, made worse by the dry conditions over the last four years, and many farmers not harvesting anything. This causes further inequity and consolidation of the sector.

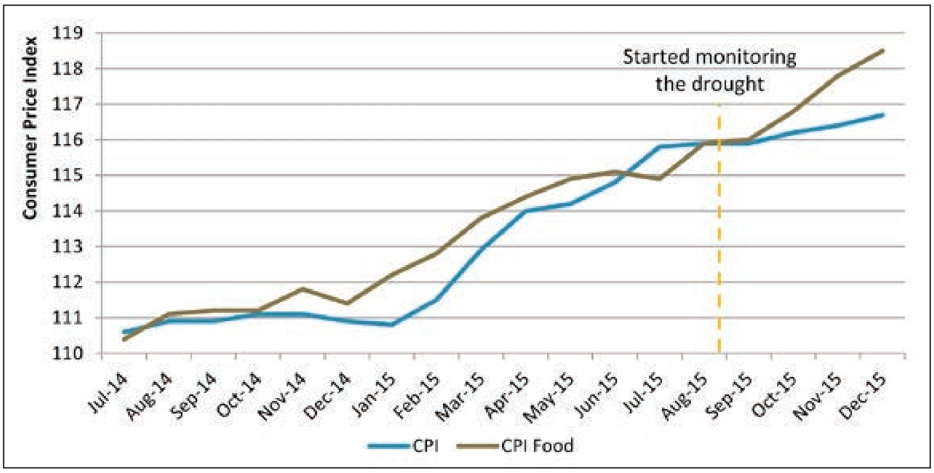
Social, economic, and food justice

Food price inflation

The impact of the drought and the weakening exchange rate are still working their way through the food value chain, and therefore we are only just beginning to feel the brunt of food price inflation (NAMC, 2016). The August PACSA report shows that a bag of 25kg maize meal has increased by 39.6% YoY, while the NAMC's food price monitoring report suggests 5kg maize meal has increased by as much as 43.7% between January 2015 and January 2016 (PACSA, 2016 and NAMC, 2016). These high inflation rates are unsustainable, particularly for the poor, who spend about 33% of their income on food, compared with more affluent shoppers, who spend about 2% of their income on food (WWF, date unknown). Food price inflation has been consistently higher than

12. Corné Louw, Senior Economist, Grain SA, 19 July 2016
13. Petru Fourie, Agricultural Economist, Grain SA, 19 July 2016

Figure 8: Consumer price index (CPI) for food (July 2014–December 2015)



Source: BFAP, 2016

total consumer price index (CPI) since this drought period.

In 2008 the global food price increase partly contributed to the wave of xenophobic violence that spread across South Africa, illustrating how increased food prices may have implications for national security. Although South Africa regularly produces a maize surplus, one in four people go to bed hungry, and diet-related, non-communicable diseases wrack the country (ACB, 2015.; Yared *et al*., 2014). The National Policy on Food and Nutrition Security speaks to the fact that 50% of South African households experience hunger (DSD and DAFF, 2013). In a country that is able to produce and procure sufficient quantities of food, this staggering figure highlights the real systemic issues that threaten people's rights to food and nutritional security.

Small-scale farmers

Most of the more than 2.5 million agriculturally active households (subsistence and smallholder farmers) are situated in the former homelands and are involved in livestock and grain (mostly maize) farming. This is primarily for household food consumption, with a small proportion generating an income from farming (BFAP, 2016).

Smallholder farmers play a significant role in household food security. In the context of the 2015/16 drought, many households that would have previously produced their own maize for consumption will now have to purchase maize at high prices, causing concern for low-income household food security and local economies. The impact of the drought on cattle farming, with reduced grazing areas, is also severe; the full effects are yet to be felt.

Despite many efforts that seek to redress the structural causes of food insecurity, inequality and social exclusion, such as the Comprehensive Agricultural Support Programme and the Fetsa Tlala Initiative, there is still no clear policy guidance on farmer support programmes and how this links with dietary patterns and health (DAFF, 2014). Programmes are embedded in an industrialised and commodified agricultural model, benefitting a few established farmers and failing to offer support to those most in need. This does little to address the underlying issues that support and maintain disparities within this sector, beyond an enterprise and economic development focus. There is an opportunity to diversify towards agroecological approaches, which supports inclusive, sustainable, and healthy food systems approaches to food and nutritional security in South Africa.[14]

14. See ACB's Agroecology in South Africa: Policy and Practices (2015) for a description of policies and programmes that currently exist to drive this approach.

Indigenous summer rainfall crops

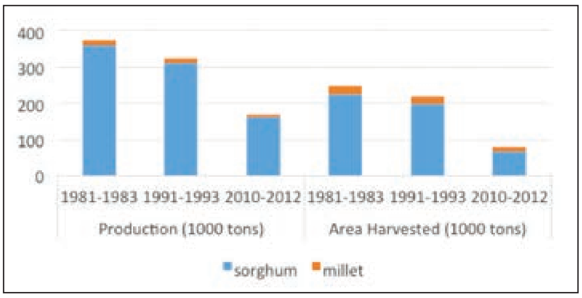
Indigenous staple crops have been systematically replaced by exotic crops, resulting in a decline in their cultivation.[15] Cereal crops, particularly maize, are important staple crops in South Africa and the region, but the most popular (exotic) cereals, maize, wheat and rice, are not drought tolerant. Climate change projections show decreases in yields of wheat (-22%), maize (-5%) and rice (-2%), with increasing drought occurrence and temperatures. On the other hand, sorghum and millet, which are indigenous to sub-Saharan Africa, are more drought tolerant and can produce under stressful conditions. According to Mabhaudhi and Modi:

> *Indigenous crops are those that have their centre of diversity in South Africa while indigenised crops are those [that], although their centres of diversity lie outside of South Africa, have been domesticated in South Africa over hundreds of years, thus making them traditional crops. Plant breeders generally refer to these crops as landraces and these play an important role as sources of genetic material for crop improvement and biodiversity. (Mabhaudhi and Modi, 2016: 40)*

Millet and sorghum are important grain crops, especially in drier parts of the continent, although they currently represent minority crops in South Africa. As with maize meal, both grains are traditionally made into porridge or pap. Despite the fact that it is currently more expensive than maize in South Africa, sorghum is often considered a "poor man's crop", whose demand declines as income rises (Orr *et al.*, 2016). This is mainly due to supply shortages caused by limited production, and sorghum's importance for household food security, which reduces the amount entering the market from subsistence farmers. While sorghum and millet are seen as insurance crops in drought years, farmers may have limited incentives to invest in raising yields. The study by Orr *et al.*, (2016) suggests that sorghum and millet will remain important food crops on the rest of the continent and will become increasingly more important in South Africa, where conditions will prevent reliance solely on maize.

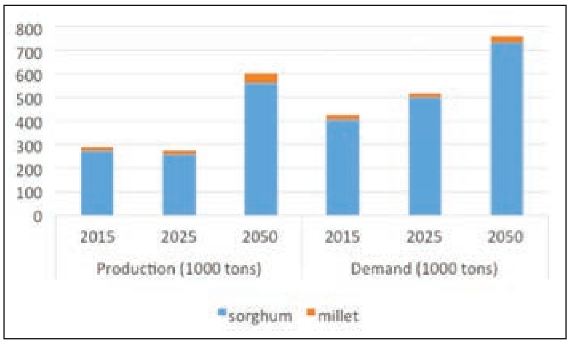
Figure 9 shows the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) model projections for sorghum and millet production across Eastern and Southern Africa for 2012–2050.

Figure 9a: Production data and area harvested of sorghum and millet 1981–2012.



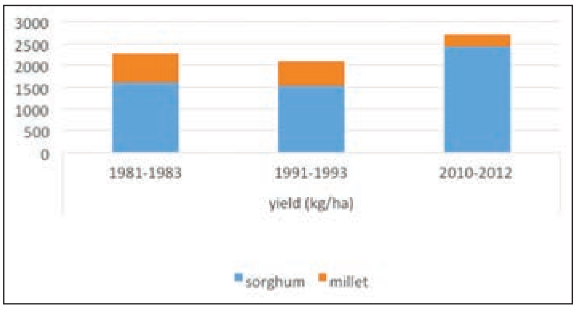
Data source: Orr *et al.*, 2016

Figure 9b: Yield of sorghum and millet 1981–2012.



Data source: Orr *et al.*, 2016

Figure 9c: Projected production and demand for sorghum and maize in South Africa.



Data source: Orr *et al.*, 2016

15. For more information on this, see ACB, 2013.

It is assumed that the main cause for the growth in demand will be population growth (Orr *et al*., 2016). Producer prices are expected to rise for both sorghum and millet over the period to 2050. Global prices for sorghum between 1991 and 2010 ranged between $100 and $200 per tonne, and prices for millet ranged between $200 and $400 per tonne. These are both considerably higher than maize prices.

Sorghum and millet are seen as crops in decline, particularly with the drastic increase in maize production globally. Yet across the continent, sorghum production has increased, while millet has stabilised (Macauley, 2015).

Sorghum and millet are biologically adapted to the drylands. They have deeper root structures and can withstand higher temperatures, without damaging the crop. Over the growing period, sorghum requires an average of 400mm of water and millet 300–350mm, while maize requires 500mm (Orr *et al*., 2016). Millet is also the best suited crop to be grown in short growing seasons. They both have higher protein content than maize, and of a better quality, and are rich in calcium and iron. However, they are susceptible to attacks from birds, which can destroy the entire crop (particularly when planted on a small scale).

Large areas of South Africa are classified as dry or moist semi-arid zones, making them ideal for sorghum and millet production. Due to local food preferences, farmers in these areas prefer to plant maize over sorghum and millet (Orr *et al*., 2016). However, with changing agroecological conditions to hotter, drier environments sorghum and millet need to be carefully considered in future crop and food production strategies.

With the advent of the current drought, researchers at the University of KwaZulu-Natal are investigating the water use and production of drought tolerant, traditional crops that may become a much needed alternative to maize (Mabhaudhi and Modi, 2016). The Water Research Council has been funding research to identify drought tolerant, underutilised, traditional crops.

Sorghum

Sorghum is currently cultivated on low-potential, shallow soils with high clay content, that are not suitable for maize production. While it requires fewer purchased inputs compared to maize (Orr *et al*., 2016) and can withstand poorer soil fertility and water stress, these factors, together with pests and diseases constrain sorghum production. Although it is mostly grown on dryland, reaching between 2.5 and 3 tonnes per hectare, when irrigated sorghum can reach 8 tonnes per hectare. *Striga*, a parasitic weed, significantly reduces sorghum yields, and is considered a major sorghum pest in Africa.

It is generally accepted that sorghum can be grown in all provinces.[16] During the 2015 season, sorghum was produced commercially mainly in the Free State (38.6%), Mpumalanga (37.8%), Limpopo (15.1%), and the North West (4.4%). Between 2014 and 2015 there was a decrease of 10.6% in the area planted with sorghum, as the expected bioethanol production facility never materialised (DAFF, 2015).

South Africa exports an average of 26,000 tonnes of sorghum per year, 98% of which is exported to Botswana (Sihlobo, 2016). With the drought that continued into 2016, South Africa became a net importer of sorghum. This year's sorghum yield is the lowest on record, with 22% YoY decrease. The estimated sorghum import of 60,000 tonnes for 2016/17 is the highest it has been since 2002/3. At the same time, there has been a 13% YoY decrease in domestic consumption. Grain SA suggests this is due to higher prices, trading at R3650 per tonne – a YoY increase of 51%.

The surprisingly poor performance of sorghum in this drought period may be due to the fact that only one sorghum cultivar is grown.[17] Maize research is well-supported through the Maize Trust, and there are prolific releases

16. Dr Nemera Shargie, Senior Researcher, ARC-GCI, 29 June 2016
17. Petru Fourie, Agricultural Economist, Grain SA, 19 July 2016

Table 2: Domestic sorghum supply and demand estimates 2014–2017

	2014/15	2015/16	2016/17
Opening stocks	50,000	121,800	57,400
Commercial deliveries	261,500	112,800	89,700
Imports	8,700	40,000	60,000
Total supply	320,300	275,000	207,000
RSA consumption	172,300	191,700	167,100
Exports	26,200	25,500	10,000
Total demand	198,500	217,200	177,100
Carry-out	121,800	57,400	30,000
Surplus above pipeline	103,000	36,000	11,000

Source: Sihlobo, 2016

of new, improved varieties of maize. On the other hand, sorghum has received very little research and development support, despite policy rhetoric to support diversified and more climate-resilient crops.[18] The Sorghum Forum is a minute body, compared to the gigantic Maize Trust. Dr Nemera Shargie, a sorghum breeder at the ARC-GCI has worked with participatory breeding programmes, and speaks of the various ways in which farmers' varieties can be improved for early maturation, improved yields, and other uses – such as the stalks for animal feed, as a fuel or as a construction material. Grain SA is also currently conducting research into sorghum varieties that are adapted to high heat conditions, but due to the less profitable sorghum market, this is not a priority.

Although sorghum has a higher protein content than maize, with an average of 10–11g per 100g protein, it is not easily digestible. This is an area that needs further research and work. However, sorghum has health and nutritional benefits: it contains relatively high levels of iron and zinc, which are important micronutrients to reduce stunting. Also, because the protein and starch in grain sorghum are digested more slowly than other cereals, it is beneficial for diabetics. Previously, sorghum cultivars on the market had to be good for malting purposes, and this influenced the release of new cultivars with high-yield potential. But as consumption patterns have changed, and there is less demand for traditional sorghum beer, the requirements have changed and more recently only one additional cultivar has been released on the market.[19]

Millet

Despite its high drought tolerance and agroecological suitability, millet is a very minor crop in South Africa compared to other countries on the continent. There is no formal body for millet farmers and information on millet production and pricing is not easily available. It is produced by subsistence farmers and for niche markets (bird feed). Pearl millet (*Pennissetum glaucum*) has the highest yield potential of all millet under drought and heat stress.

As part of a recent study, the use of millet as a cover crop in an intercropped conservation agriculture maize system showed millet to have performed well during drought conditions, while the maize in the same field failed (Kruger, 2016). More attention should be given to this indigenous cereal grain, beyond simply its use as a cover crop. Millet is gluten free and rich in fibre, iron and calcium, containing as much as 40 times more calcium than maize and rice, and 10 times more than wheat. Its high iron and calcium content explains why it is used to wean children onto solids, and by lactating and pregnant women.

18. Dr Nemera Shargie, Senior Researcher, ARC-GCI, 29 June 2016
19. Corné Louw, Senior Economist, Grain SA, 19 July 2016

Research and development in maize and sorghum

There is over-investment in maize research and development, which is far more established than any other crop. The Drought Tolerant Maize for Africa project has released 160 maize varieties since its inception (of which at least 94 are hybrids), while AGRA's Program for Africa's Seed Systems (PASS) released 118 maize varieties by the end of 2014. In comparison 28 varieties of sorghum and just 13 varieties of millet have been released (AGRA 2014). This provides an indication of the extent to which research is done on maize, while other potential drought tolerant staples are virtually off the radar.

The Bill and Melinda Gates Foundation-funded HOPE project (Harnessing Opportunities for Productivity Enhancements) is working with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) – who has the mandate for research and development of sorghum, pearl millet and finger millet – to counter the shrinking markets of sorghum and millet by stimulating research on farming, enhancing technology adoption, enhancing the value chain and markets, and through capacity building.[20] This project operates in west and east African countries,[21] and by using improved cultivars and agronomic practices yields as low as 17% have reached as high as 141% (Macauley, 2015). Projects such as this one need to be monitored carefully.

Shifting trends

Towards non-GM maize

Previously South African consumers had no option but to buy GM maize meal for their daily food. However, major retail giant, Woolworths, recently released a non-GM maize meal line, despite the difficulty in securing non-GM maize in South Africa. The non-GM maize meal is priced similarly to its GM counterparts: 2.5kg non-GM maize meal is R26.95, while 2.5kg Ace is R26.95, IWISA R28.95 and White Star R25.95. This is a positive step forward, although Woolworths is generally more expensive than other retailers. The majority of consumers who buy maize meal as a staple food in larger quantities from cheaper retailers are still left without any options. Hopefully more brands and retailers will follow this trend, and give consumers greater choice (ACB, 2016). This said, the production methods continue to operate within the ecologically unsustainable monocrop industrial agriculture system. Recently, SA Rice Mills, a family-owned business, commissioned the first mill in South Africa to be made available to focus exclusively on non-GMO maize (Food Processing Africa, 2016), indicating that a slow paradigm shift is taking place in the South African maize sector. The company was motivated by the high demand for non-GMO products from neighbouring countries and other export markets that have anti-GMO policies, limiting export potential for South African maize producers.

> *To mill non-GMO maize, conventional millers would need to stop their entire line, purge it, and clean it ferociously to prevent cross-contamination that would prevent them from labelling the product non-GMO. This cleaning […] can take up to a day and a half, which translates into two days of lost production and this has to be factored into the cost. (Food Processing Africa, 2016: 8)*

Where previously non-GMO maize meals could not have been sold at competitive prices, a mill dedicated to non-GMO processing removes the costs associated with halting operations. This very positive development potentially opens hitherto closed doors, towards transforming of the maize value chain.

20. See http://hope.icrisat.org/
21. Sorghum and pearl millet systems are being implemented in West and Central Africa (Burkina Faso, Mali, Nigeria, and Niger), and sorghum and finger millet systems are being implemented in East and Southern Africa (Eritrea, Ethiopia, Southern Sudan, Tanzania, Kenya, and Uganda). There are also projects in India.

Commercial farmers shift to conservation agriculture

Crop production systems in South Africa are based on intensive and continuous soil tillage and have led to severe soil degradation, particularly in grain producing areas (Blignaut *et al*., 2015). In light of the need to transform the current paradigm of agricultural production and management towards sustainable agriculture methods, conservation agriculture has gained momentum and has been broadly adopted and promoted by the South African government. Grain SA has a conservation agriculture programme, led by Dr Hendrik Smith. The three guiding principles include: minimum tillage and soil disturbance, permanent soil cover with crop residues and live mulches, and crop rotation and intercropping.[22]

Many of Grain SA's members are moving in the direction of conservation agriculture, since production costs are rising rapidly and profit margins are getting smaller.[23] About 40% of maize farmers have shifted to some version of conservation agriculture. Most are maintaining high inputs, but Dr Hendrik Smith is encouraging a shift to fewer inputs to reduce risk and improve the soil conditions, as well as to benefit the environment more broadly. This is the long-term vision, as the industry is "addicted to chemicals".[24] He estimates that South Africa's soil has lost 50–75% of its carbon, and is very much degraded.

Jurie Bezuidenhout, a commercial maize farmer in the North West province, began doing his own research on diversified farming and how to improve the soil, in order to find answers to the question: "How can you be sustainable on a degraded resource? ... If the soil is healthy the food will be healthy, and we will be healthy."[25] He has shifted to conservation agriculture, with no tillage, cover crops and intercropping, and is reducing input costs every year. On his farm, they no longer use Roundup or grains stacked with *Bacillus thuringiensis* (Bt), stating, "If cattle and livestock don't want to eat it, and worms don't want to eat it, how do people want to eat it?"[26]

From an agronomic perspective, conservation agriculture is a good set of practices to transition the sector (see Figure 10). Dr Hendrik Smith, who is leading the conservation agriculture programme at Grain SA, a position funded by the Maize Trust, focuses heavily on the need to diversify on-farm practices. But the highly mechanised aspect of conservation agriculture means that each crop added is capital and knowledge intensive. Currently the type of crop rotations can be considered "glorified monocultures" with farmers rotating between GM soya and GM maize, and in the western parts of the country rotating between GM maize and sunflower.

In smallholder systems Grain SA is encouraging maize-based systems with dense intercropping, including beans, cowpeas and millet, amongst other cover crops. Because access to seed for cover crops is limited, they encourage reusing seed, where it is lawful;[27] current plant breeders' rights laws in South Africa prevent farmers from reusing protected seed commercially. There is also a strong focus on on-site learning and social-learning processes amongst farmers through farmer forums and farmer innovation programmes.

Dr Smith has noticed an increasing trend of farmers turning to OPVs, in order to reduce cost and risk.[28] OPVs might have a lower yield, but are cheaper than hybrid maize varieties/GM varieties and outperform these others in terms of profit, since OPVs require fewer additional inputs. Hybrid maize seed costs about R1000 per hectare, while OPVs cost R400–R500 per

22. http://www.fao.org/resources/infographics/infographics-details/en/c/216754/
23. Petru Fourie, Agricultural Economist, Grain SA, 19 July 2016
24. Dr Hendrik Smith, National Conservation Agriculture Facilitator, Grain SA, 19 July 2016
25. Jurie Bezuidenhout, commercial maize farmer, North West province, 29 July 2016
26. Jurie Bezuidenhout, commercial maize farmer, North West province, 29 July 2016
27. Dr Hendrik Smith, National Conservation Agriculture Facilitator, Grain SA, 19 July, 2016
28. Dr Hendrik Smith, National Conservation Agriculture Facilitator, Grain SA, 19 July 2016

Figure 10: Typology of different conservation agriculture grain production systems

Stage	1	2	3	4	5	6	7
Type of farming system	Conventional Tillage	Minimal or reduced tillage	Conventional no tillage (NT)	Conventional zero tillage (ZT)	Conservation agriculture – high external inputs	Conservation agriculture – low external inputs	Organic conservation agriculture

Sustainability gradient →

Source: Blignaut, 2015

hectare. Jurie Bezuidenhout is working with Capstone to find an OPV solution by developing varieties best suited to his context.[29] With the droughts in the last three to four years, farmers have become increasingly cash-strapped, and the high inputs of hybrid and GM maize production put them at even more financial risk.[30]

Research is urgently required on intercropped systems, as even at ARC no research is currently being done on diverse crops within agroecological systems. New varieties are tested in monocropped systems, with high inputs.[31] This dearth of information on the performance of different cultivars and different agricultural practices (particularly diversified farming practices) gives little indication and few options for farmers to experiment with best practices for their sites and contexts.

Dr Smith reiterates that the training being passed on at agricultural colleges and through extension officers is problematic: "They are stuck in old paradigms".[32] He believes that despite farmers being researchers in their own right, their knowledge is often exploited. Due to under-resourced government extension services, fertiliser companies and agribusinesses have entered the void by providing extension support to farmers and promoting agrochemical products and associated improved seeds. There is an urgent need to address the agricultural education curriculum and provide more support for public extension services that are not schooled in the Green Revolution dogma.

29. Jurie Bezuidenhout, commercial maize farmer, North West province, 29 July 2016
30. Jurie Bezuidenhout, commercial maize farmer, North West province, 29 July 2016
31. Dr Nemera Shargie, Senior Researcher, ARC-GCI, 29 June 2016
32. Dr Hendrik Smith, National Conservation Agriculture Facilitator, Grain SA, 19 July, 2016

Comparing agricultural practices

The Rodale Institute's 30-year Farming Systems Trial (FST) study, comparing organic agricultural and chemical agricultural production systems, provides critical information to assess these different farming systems and provide concrete evidence in support of organic agriculture. The study compares maize and soybean production with a manure-based organic system, a legume-based organic system, and a synthetic input-based conventional system. GM crops and no-till treatments were incorporated into the study, representing the shift in farming practices in the United States. The main findings included:

1. Organic yields match conventional yields.
2. Organic outperforms conventional in years of drought.
3. Organic farming systems build rather than deplete soil organic matter, making them more sustainable.
4. Organic farming uses 45% less energy and is more efficient.
5. Conventional systems produce 40% more greenhouse gases.
6. Organic farming systems are more profitable than conventional systems.

Figure 11a: Comparing organic and conventional production – yields

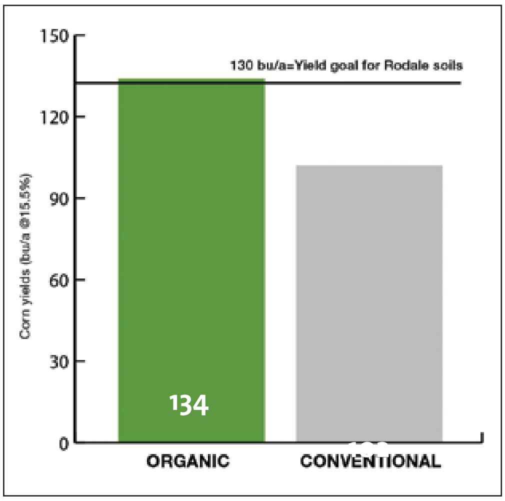


Figure 11b: Comparing organic and conventional production – income and expenditure

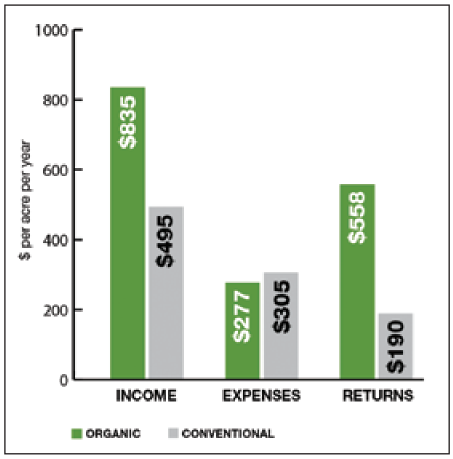
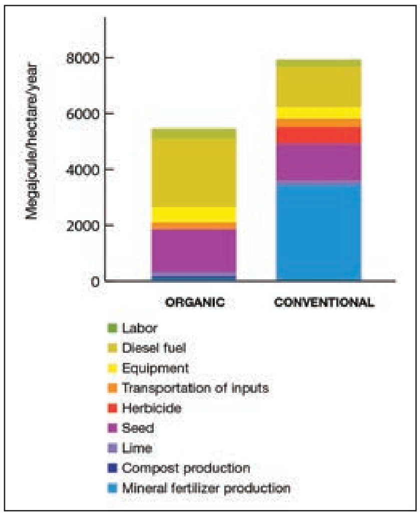


Figure 11c: Comparing organic and conventional production – inputs



Source: Rodale Institute, 2011

Organic corn yields were 31% higher in drought years. This is remarkable compared with GM "drought tolerant" varieties, which saw increases of only 6.7%–13.3% over conventional, non-drought resistant varieties (Rodale Institute, 2011). Traditional plant breeding of major grain crops have increased yields three to four times more than GM varieties, with GM crops leading to an explosion in herbicide use.

The diesel fuel was the single greatest energy input in the organic systems. (Rodale Institute, 2011). Reduced diesel costs are associated with GMO cultivation.[33] Organic production was three times more profitable than conventional, and more profitable even without the price premium. In the Rodale FST, the no-till conventional maize (the typical form of conservation agriculture) was the least profitable (Rodale Institute, 2011).

These findings provide evidence to counter the conventional agricultural path, and to develop a roadmap to transition out of the current system towards an agro-food system that supports and nourishes both producers and consumers.

The way forward: Transitioning to diversified food systems

Following the International Assessment on Agricultural Science and Technology Development (IAASTD) study, there is growing interest globally in agroecological practices that offer ideas on regenerating biodiversity, absorbing excess carbon dioxide from the atmosphere, improving soil fertility and water retention capacity, and contributing to healthier and more diverse diets. The process is still in its early stages, developing practical modules for experimentation, support and expansion of agroecological activities, but there is room to work in this direction.

There is growing evidence that agroecology farming systems, including organic agriculture, can feed a growing population while generating significant economic, health and environmental benefits (Cook *et al*., 2016). Agroecological farming methods could double global food production in just 10 years, according to the UN, and create more jobs than conventional agriculture, as more money is invested in people in an organic farm operation (Rodale Institute, 2011). Agroecological farming systems are crucial to feeding a growing global population, protecting livelihoods and conserving ecological integrity to sustain future generations for both developed and developing nations (Cook *et al*., 2016).

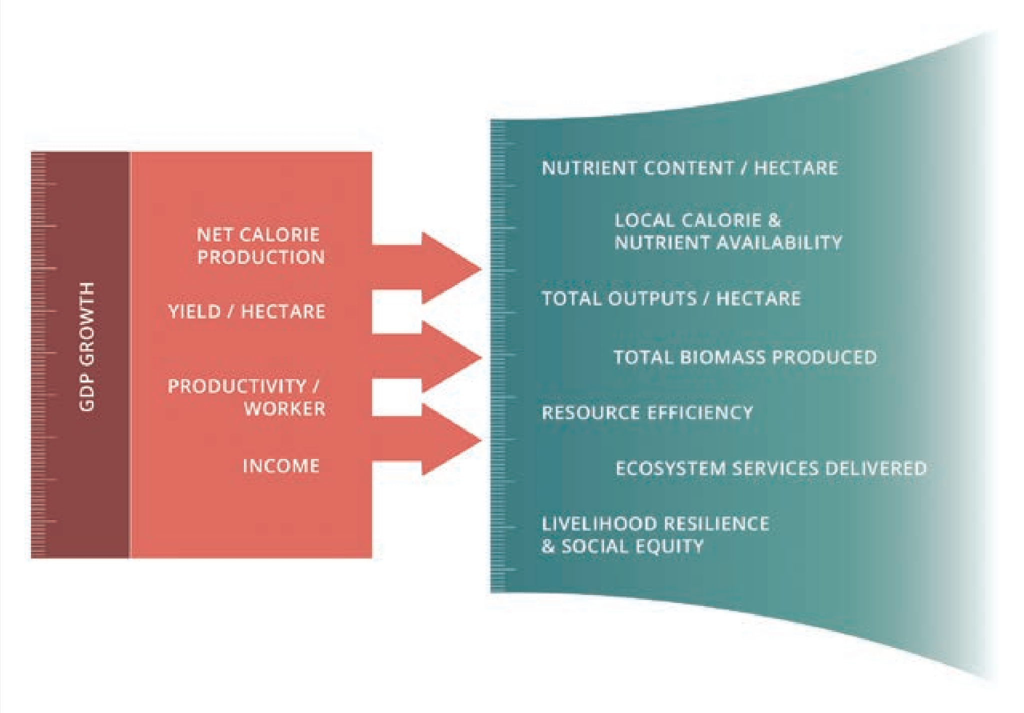
Most efforts to maintain, sustain and increase agricultural production (in increasingly precarious conditions) have focused on improving seeds and having sufficient agro-inputs, reinforcing the model of industrial agriculture. Agroecology seeks to improve the sustainability of agroecosystems by reinforcing natural processes, rather, and simultaneously increasing farm productivity and food security, improving incomes and rural livelihoods, and reversing trends in species loss and genetic erosion (De Schutter, 2010). It supports building drought resistant agroecosystems (that is, soils, plants, biodiversity, etc.), and not just focusing on improving certain plants to be more drought tolerant (De Schutter, 2010). This approach goes beyond sustainable agricultural practices to include cultural and social justice as central principles in food and farming systems (Cook *et al*, 2016).

New indicators must be developed to best understand the performance of cultivars beyond yield, profitability and calorie content, and broadened to take into account other factors, including tolerance to different conditions and nutritional value, amongst others. This is best achieved by supporting agrobiodiversity and seed sovereignty, and preventing the expropriation and exploitation of thousands of years of co-evolution and knowledge sharing. The technological fixes, which are supported by draconian seed laws, undermine resilience by reducing the value of seed from that of a public good to a mere commodity.

More public funding is required to research agroecology techniques, particularly around diversified farming practices on yield performance; increasing farm diversity and nutrition security; and developing systems that can lead to a more democratic and inclusive food system, based on food sovereignty and social justice. Agroecology is central to food sovereignty, which is a global

33. Wessel Lemmer, Senior Agricultural Economist, ABSA Agribusiness, 8 July 2016

Figure 12: Measuring what matters for sustainable food systems



Source: IPES-Food, 2016: 68

movement advocating a transformed food system whereby producers, distributors and consumers are the drivers of food policies. Food sovereignty differs markedly from food security, as it is possible to achieve food needs without addressing the economically and environmentally exploitative conditions of the current industrialised and commodified food system (Cook *et al*., 2016). The South African Food Sovereignty Campaign, amongst others, is driving this agenda in South Africa, working with community organisations and small-scale farmers to push for agrarian reform and ecological, social and economic justice.

Consumers are beginning to demand non-GMO maize meal options, although this is currently taking place at higher socio-economic levels, and for the export market. This movement towards non-GMO options, and the growing demand for such products, which are stimulating new innovations, is a positive step forward. However, there needs to be a broader-based shift in consumer mind-sets towards healthier and more nutritious foods. This also requires a shift at the policy level, to transform the agenda away from a yield- and volume-driven agricultural system, which is creating nutritionally deficient soils and societies. There is no agency responsible for ensuring the right to safe, adequate and nutritious foods. To achieve this, there needs to be collaboration between the agriculture, health, social development and trade departments, to support the production, accessibility and affordability of quality foods that support sustainable agriculture and health.

ACB maintains that new technological fixes, such as the GM drought tolerant maize varieties, reinforce the vulnerabilities associated with industrial agriculture, and should be replaced with real agrarian reform and a transition to agroecology, in order to create resilient agro-food systems that can safeguard a diverse food supply and ecological health as we move into a dry future (ACB, 2015).

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african centre for biodiversity
PO Box 29170, Melville 2109, South Africa
www.acbio.org.za