Sustainable agriculture: A viable option for enhanced food and nutritional security and a sustainable productive resource base in South Africa: An investigation

Deliverable 2: Baseline Review

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Executive Summary

The world will need almost double the current food supply by 2050 to feed approximately 9 billion people. However, there will be less land, water and energy available, and there will have to be much less degradation and pollution of natural support systems. In addition, agriculture will have to support further economic development, a situation which has been referred to as the “Great Balancing Act”. Approximately 870 million people globally are undernourished. Close to 100 million of these people are in the southern African Development Community (SADC) alone. An estimated 25% of South Africans are still food insecure and it is further likely that 30–40% of food produced in the field is wasted throughout the food system.

Sustainable agriculture has been proposed as an alternative to conventional farming systems. The conditions under which a transition towards a more sustainable agriculture and food system would be successful is a matter of intense debate and of utmost importance to South African agricultural and food policy in the immediate future. The central idea of sustainable agriculture is to enhance agricultural productivity by managing the natural resource base in a more sustainable way. This can be done, for example, by diversifying crop rotations, using organic soil nutrients, reducing soil erosion, improving water-use efficiencies and making increased use of biological regulation functions. Several high-level studies mention the possibility of socio-economic improvements as a direct result of sustainable agriculture. These improvements could include the creation of green jobs, achieving synergies between poverty alleviation and the green economy, the possibility of the green economy being an engine for development, and growing export markets for green and sustainable food. In the aftermath of financial and debt crises around the globe and an increased realisation of the intensity of ecological crises, economic growth and development models are clearly under scrutiny again. In the South African context, the next step is to empirically test alternative forms of sustainable agriculture as central components of the green economy and to identify options that would deserve further policy intervention.

A baseline review was conducted and the results of this review is contained in this report. Information is presented on alternative farming systems, food production and some consumption trends, food waste, food value chains, natural resource use and impacts on ecosystems, climate change, food security and nutrition, as well as policies, strategies and governmental institutions available to support an agricultural and food transition towards a greener economy.

Further, the results of this baseline review will inform the following issues:

- Further research that is needed on sustainable production systems, consumption trends, agricultural value chains, food security and nutrition, institutional models as well as policy instruments to affect desired change.
- The policy processes and engagement with institutions in the green economy.
- The development of a sustainable agriculture system dynamics model capable of simulating various options in the quest to achieve a more sustainable agriculture.
**What is sustainable agriculture?**

The main emphasis in sustainable agriculture is on fostering synergies between agricultural production, conservation and rural livelihoods. For the purposes of this project we use categories developed in the literature on sustainable agriculture and start with the term Conservation Agriculture (CA). CA can be conceptualised as a stepwise and gradual process including production stages like No-Till (NT) or CA with high external inputs (HEI) and CA with low external inputs (LEI). The most sustainable form of an agriculture production system is here portrayed as Organic Conservation Agriculture (OCA). CA refers to a farming system where three principles are applied simultaneously. These three principles are minimum disturbance of the soil, year-round soil cover and sound crop rotations including legumes. OCA is based on these three CA-principles and enhanced with management systems and approaches (as depicted in Figure 1 in this report).

However, organic agriculture is characterised by decreased yields and higher prices compared to conventional agriculture, raising valid questions pertaining to a strategy singularly focused on OCA to achieve food security objectives. Instead, a gradual process from conventional ways of farming to alternatives gives a better understanding and highlights the plurality of alternatives to both conventional and organic. Conservation tillage leaves at least 30% of crop residue on the soil surface. Minimum or reduced tillage refers to the minimum amount of soil disturbance which can be achieved using the equipment available to the farmer. No-Till (NT) is defined as disturbing the soil as little as possible – only up to 25% – by using tine planters or a combination of tine and disc planters. The main differentiating factors in defining and comparing alternative farming systems over its various stages are the quantity of external inputs used, the type of tillage technology used, the amount of soil cover left and the frequency of using multiple crops.

**How far has South Africa progressed already?**

The next question addressed in this report is how far South Africa has already progressed towards a more sustainable agriculture and food system. Concerning field crops, approximately 70% of South Africa’s cereals and 90% of its commercially-grown maize is mainly rain-fed on the Highveld. However, both water scarcity and soil degradation are pressing issues. Commercial farmers, producing 95% of South Africa’s food, are heavily dependent on fertilisers to maintain yield levels. This results in roughly 60% of the cropland area in South Africa being moderately to severely acidic in the topsoil, while 15% of the cropland area is affected by subsoil acidity. Cover crop trials have been conducted in the eastern Free State with good results in water-use efficiencies and suppressing weeds. Further, one of the main causes of land degradation is intensive tillage used during land preparation, planting, and weed and pest control. Commercial farmers in South Africa have already started reducing tillage on their farms. Conservation tillage (CT) and No-Tillage (NT) are gaining more acceptance in South Africa. An estimated 35% and 9% of total hectares in South Africa was under CT and NT respectively in 2004.

The horticulture subsector plays a significant role in the agricultural economy due to a strong export focus and its labour-absorbing ability. In 2010/2011 the citrus industry specifically contributed R6.9 billion to the total gross value of South Africa’s agricultural production, representing 19% of the total gross value of horticulture. Farming systems are predominantly conventional, relying on intensive management and inputs of agro-chemicals (although mostly with Integrated Pest Management). This has been justified both from a profitability point of view...
and because of the strict phytosanitary requirements of export markets. Efforts to reduce chemical inputs and increase efficiencies of inputs have been driven by demands of the export market and input price concerns (mainly market access and profitability) rather than ecological/health concerns.

Commercial production of fruit crops is very water-intensive and almost entirely under irrigation. Water resources in many of South Africa’s core horticultural production areas are coming under increasing pressure from other major users. Much of the deciduous horticultural production of the Western Cape takes place in soils of poor fertility, and regular fertilisation is standard practice in order to achieve consistently high yield and quality. Other inputs include herbicides, pesticides, fungicides and rest-breaking agents (for apples). Intensive industrialised agriculture, together with other drivers, has contributed to the deterioration of water quality in certain catchments.

Precision agriculture has been adopted by some fruit and wine producers in an effort to increase efficiencies of inputs such as fertilisers and irrigation, and to optimise crop growth and product quality. The debate concerning “soil health” and biological approaches to soil management has been ongoing in the fruit industries for many years, with conflicting or inconclusive research results, and little agreement on what this is and how to achieve it. The soil component of sustainable farming (cover, soil biodiversity, etc.) cannot be regarded as satisfactory within the mainstream horticultural sector. Soil and water resources are still impacted negatively by intensive horticulture and further interventions are required towards a more sustainable system. There are several barriers towards adopting more sustainable practices in horticulture, including costs, the difficulty in isolating organic from intensive farms, small and slowing demand for organic products, and unstable land tenure systems.

Livestock is the largest agricultural sub-sector in South Africa, contributing approximately 25–30% of the total agricultural output per annum. The area involved in cattle, sheep and goat farming in South Africa represents 53% of all agricultural land. Rainfall is a major driver of national herd size, notably cattle. However, there are also concerns of the effects of overgrazing on soil characteristics, as well as bush encroachment and the available of palatable grass species. In all cases, beef production is by far the most water-intensive food using a global average of 15 400m$^3$/ton produced. There are approximately 14 million cattle in the country (80% of which are beef and 20% dairy), as well as 24 million sheep, 6 million goats and 1.6 million pigs. Almost 2.2 million cattle, 4.6 million sheep and lambs, and 2.5 million pigs are commercially slaughtered per annum. Feedlots are used to fatten animals quickly and now account for 75% of all beef production in South Africa. Feedlot cattle show higher profits than conventional or organic pasture cattle, but issues around animal welfare and the use of penicillin, vaccinations and growth hormones have been raised. Cattle productivity in the smallholder sector is declining due to the prevalence of diseases and parasites, a lack of feed resources, and poor breeding and marketing management. Cattle under commercial systems still spend considerable time outside of feedlots and are either directly or indirectly grass-fed. The extensive grazing system of South African producers is often referred to as under-stocked and overgrazed and most of South Africa’s grazing land is already stocked beyond its long-term carrying capacity. Sustainability regarding beef or cattle production includes the same elements as the other systems: striving to have a lower carbon footprint, reducing GHGs, increasing water-use efficiency, improving the soil and grazing, integrating pest management, and improving the profitability in the sector. There were a number of certified cattle farmers in 2002–2004 but due to various difficulties, certified organic beef production is no longer a feature of the South African organic industry.
Towards a Sustainable Agriculture Food System

As the achievement of multiple objectives is an important feature of sustainable agriculture, a holistic systems approach to farming is required, relying on knowledge-based development of whole farms and communities to address the myriad of socio-economic, ecological and political challenges in sustainable agriculture. For the purposes of this review, a Sustainable Agriculture and Food System (SAFS) is defined that includes farming, food security and agro-ecological subsystems. The focus now moves to a discussion of food distribution across the value chains, the quality of the system in relation to resource use, environmental impact, employment and human dignity, and the issue of food security and nutrition.

Value chain analysis

Agriculture has some of the strongest backward, forward and employment multipliers in the economy. For dryland maize, beef cattle and citrus the following are considerations to achieve sustainability:

- The intensity of resource use, especially water and energy:
  - in the production, milling and transport of maize
  - in the manufacture of feed, livestock rearing, and in abattoirs and other forms of processing for beef
  - in the production, packaging and processing of citrus

- The management of waste

- The use of chemicals:
  - especially pesticides and fungicides in various parts of the value chain for maize
  - for health management and processing in livestock production
  - in production, packaging and processing to meet the local and international requirements for allowable residue levels for citrus

- Reducing carbon footprints especially linked to on-farm fuel, electricity and fertiliser use:
  - for maize, most of the energy used (and thus the carbon footprint) is linked to the production of fertiliser and on-farm practices
  - for beef it is mainly linked to feed production; however, imported meat would have a higher footprint owing to the carbon emissions associated with long-distance shipping of chilled/frozen product
  - for citrus it is mainly linked to on-farm use of electricity for irrigation pumping, synthetic nitrogen fertilisers, and diesel; the use of virgin packaging material, electricity for cooling, and the transport component, especially for exported fruit

- The level of real free market opportunities
  - as opposed to high concentration and monopolies in parts of the secondary and tertiary value chain for maize
as opposed to high concentration and monopolies in parts of the secondary and tertiary value chain, especially a high degree of vertical integration for beef

- as opposed to the increasing degree of vertical integration especially by the dominant local and foreign retailers which can lead to monopolies and barriers to entry for citrus

- The potential impact of the emerging biofuels industry should maize eventually be allowed as a feedstock

- The use of genetically modified (GM)-containing feeds in livestock rearing and an inability on the part of the consumer to ascertain which products contain GM maize to make a personal informed choice

- Uncertainty around the safety of GM maize and an inability on the part of the consumer to ascertain which products contain GM maize to make a personal informed choice

- Opportunities within the value chain for sustainably-produced maize, beef and citrus to be processed, marketed and promoted in a differentiated manner
  - for example, specifically organic beef has not been able to gain market entry

The following are additional considerations to achieve sustainability in the citrus value chain:

- Maintenance and investment in supporting infrastructure such as roads, port handling facilities and electricity supply

- The high administrative burden and cost of certification of sustainably produced citrus (i.e. organic citrus)

A specific issue that deserves further attention in value chains is to link emerging and smallholder farmers to agri-food supply chains for sustainable production systems. Smallholder and emerging farmers require linkages with the input and output markets in the same manner as commercial farmers. The outcomes to date have not been encouraging owing to a multitude of barriers. While vertical integration and its economic benefits have become entrenched in the commercial sector, emerging and smallholder farmers rarely have the resources to achieve this even when combined into a group of small producers. The success of CA depended on the quality of extension and research services provided. If emerging and smallholder CA in a specific province are to succeed so that CA can be scaled up across the country, technologies for CA suited to their particular conditions and budgets will have to find greater support from research, extension and input suppliers, as well as some policy adjustments.

How does income and prices transmit through value chains? Indications are that retailers respond more quickly to shocks that stretch their market margins rather than to those that squeeze it, a situation attributed to the anti-competitive nature of the food market chain. Parts of the maize supply chain (milldoor to retailer) and the beef supply chain, suffer from such asymmetric price transmissions, but the maize supply chain (farm gate to miller) did not show these characteristics. South African producers already deal with a significant cost-price squeeze caused by a disproportionate increase in the costs of production as compared to producer prices, and research on CA in the Western Cape clearly has shown the financial benefits to producers of changing from conventional to CA production systems in certain cases.

By and large, the mainstream commercial agri-food value chains are not well-positioned to serve the needs of sustainable agricultural production systems. Since retail supermarket chains in
South Africa do not provide easy entry for organic produce owing to difficult demands for volumes and consistent quality, outlets such as farmers’ markets and other direct marketing avenues provide alternatives. Price premiums are, however, not guaranteed. This has led to the situation where most of the organic produce grown in South Africa is exported. Ultimately, CA/OCA must gain acceptance across the value chain and be demanded by informed South African value chain actors and consumers if it is to succeed and scale up as a dominant paradigm.

**Quality of the food system**

The focus now changes to the quality of the food system, including a focus on the quality of the food delivered, the demands of the system on natural resources, the loading of pollution and waste back into the environment and aspects of food security. The quality of food can be assessed variously as the overall quality of the diet (nutrition), the safety of the food consumed (in terms of risk to cause illness or even death), and the quality of a specific food type grown under different production systems. A recent analysis on the relationship between undernourishment across SADC and various food system indicators, found the following:

1. A generally insufficient intake of carbohydrate and protein, but proportionally too much carbohydrate.
2. Mostly an insufficient intake of essential micronutrients.
3. A strong relationship between an increase in undernourishment and a decrease in the consumption of fruits and starchy roots.

In South Africa, sufficient food, including fresh fruit and vegetables, is almost always available, but still a high number of South Africans suffer from poor nutrition. Even in urban areas where food supply chains exist and fruit and vegetables are usually freely available, a high proportion of people either cannot afford or choose not to buy these foods, a situation that impacts on children as the most vulnerable group.

**Food safety**

Food safety is further a primary concern for the agro-food industry. The food sector is subject to stringent legislation and regulation aimed at ensuring that food reaching the consumer is not harmful to his/her health. Despite these measures there exist a number of risks to food safety which appear to be increasing. Contamination in South African river water that is used for irrigation purposes shows high concentrations of faecal indicators and numerous other pathogens which can cause severe illnesses in humans. The potential impacts on agriculture can be harsh, particularly for fresh produce aimed at the export market. Furthermore, not only are river systems (and groundwater in some cases) negatively affected by some industrial agricultural practices, but soils can also become contaminated with heavy metals and other toxins owing to long-term use of toxic agro-chemicals. These then make their way into the food system.

**Natural resource use and environmental impact**

Agriculture uses natural resources and impacts the environment with pollution and waste. In South Africa, agriculture uses 63% of freshwater, occupies 79% of total land area and uses less than 1% of total energy. Nutrient levels exceed recommended water quality guidelines for plant life in all but one of South Africa’s 20 largest river catchments. Many studies have highlighted the
occurrence of pesticides in water resources as well as its possible effects on food safety and public health. The agricultural sector contributes 5% of the country's total net greenhouse gas emissions, mainly through enteric fermentation in ruminant animals.

Food security

South Africa is considered nationally food secure – at a national level there is enough food available for the whole population. Overall production levels and food supply have kept pace with population growth and even exceeded it. Household food production is making a small contribution to providing for the needs of individual households, but this is variable across the country. South African cities have unusually low rates of household food production. Taking a longer-term view, the current ability of South Africa’s farmers to continue meeting the increasing demand for food is expected to be tested by the emerging impacts of climate variability and climate change on production. The trend towards greater consumption of wheat, fuelled by the preferences of the growing middle class, could see the country moving into a situation of production deficit and net import of grains.

Food security in South Africa is largely about direct or indirect access to cash to purchase food. South African basic food prices increased steadily across a broad spectrum of a food basket. This is particularly important when looking at the urban context, where purchasing food is the dominant means of accessing food. The country is further experiencing a nutrition transition in which under-nutrition, notably stunting and micronutrient deficiencies, co-exist with a rising incidence of overweight and obesity and the associated consequences such as hypertension, cardiovascular disease and diabetes. Rates of childhood stunting (18% of children under 6 years) are comparable to low-income countries in the region, indicating a chronic or severe deficiency in essential nutrients/micronutrients during the growing years – a significant concern in South Africa. Eleven of the 17 most common risk factors for deaths are directly or indirectly related to nutrition. A general decrease in the experiences of hunger by households is observed, but rates of stunting, micronutrient deficiencies, and hunger and food insecurity continue to be unacceptably high. One explanation is a growing dependence on market purchases for procuring food in South Africa. The location of supermarkets in Cape Town illustrates the highly unequal structure of the urban food system that limits the urban poor from accessing healthy foods. In contrast, urban farming may contribute to household income and food security.

So far, an overview was given of the main aspects that characterise the South African farming, food and nutrition system. The question that has not been addressed yet is whether the great balancing act of feeding more people in a more sustainable way can in fact be achieved through alternative farming systems. Therefore, the next step is to provide a brief overview of the main results worldwide, and more specifically South(ern) Africa, on comparisons between conventional and alternative agricultural and food systems.

Comparing conventional and sustainable agriculture and food systems

Drawing on several meta-analyses worldwide, a few key observations can be made:

- Increased economic benefits are not directly associated with organic farming, conservation agriculture, or NT technologies.
- Yields are typically lower for organic farming systems, but much variation occurs.
Positive impacts of alternative farming systems on environmental indicators are most notable for soil organic matter (SOM) and biodiversity indicators.

Apart from SOM and biodiversity gains, the only environmental impacts that differ significantly between organic and conventional farming systems (in Europe) are nitrogen leaching, nitrous oxide emissions per unit of field area, energy use and land use.

Organic production may offer "... significant GHG reduction opportunities" by increasing the soil organic carbon stocks.

Results are divided on the differences in nutritional quality of organically- or conventionally-produced food.

The benefits of applying CA to South(ern) African farming systems has been pointed out in various field-level studies, but the uptake of CA in sub-Saharan Africa is very slow. Constraints to adoption include competing uses for crop residues, increased demand for labour for weeding, and lack of access to needed external inputs. A key challenge for CA in small-scale (southern) African farming systems is to gather empirical information on all aspects of CA across various scales and regions and to devise strategies to mainstream and upscale the approach. No empirical studies were found that measured the different outcomes of conventional and alternative horticulture production systems in South Africa, but several studies do report on natural resource and environmental indicators. For beef, not many empirical comparative studies on alternative beef production systems were found in South Africa either, but one study did find that feedlot cattle showed a higher profit than conventional and organic pasture groups, mainly due to faster and more efficient growth. Other studies indicate that organic beef production had lower ecological and carbon footprints relative to conventional beef production.

Comparative studies between conventional and alternative systems have been and can be done, but need to be sensitive to various issues, such as the technologies used, site-specific conditions, expression of environmental impacts per area and per product, type of environmental impacts measured, the need to include indicators for nutritional quality, the need for context-specific economic analysis, and the need for a systems perspective beyond field-level comparisons.

Institutional and policy context

The next question addressed is how change can be affected towards the desired outcome of sustainable farming systems, shifting focus to what is required from an institutional and governance perspective in achieving more sustainable agriculture and food systems.

South Africa is characterised by a strongly-defined dual agricultural economy, with highly-concentrated food production by contract farmers for agri-processing companies focused on modern urban markets as well as extensive smallholder farmers. Institutional arrangements in the South African agricultural sector are generally characterised by weak governance and governance structures, resulting in poor/fragmented implementation of existing programmes. The South African government has struggled for over two decades to adequately define the right to food and to develop a comprehensive legal and policy response to the issue. Policies dealing with the right to food, loosely arranged to address the elements of food security, have remained in silos and sometimes in contradiction to each other.

In terms of food availability, the various policies around agriculture are important to understand. Since 1994, policies in agriculture have had three main focus areas in common, namely improving...
competiveness of commercial agriculture in a free market dispensation, improving participation by the disadvantaged communities, and protecting the natural resource base. A further challenge is that while South Africa may be food secure as a country, large numbers of households within the country remain food insecure.

The most recent Strategic Plan for DAFF (2012/2013 to 2016/2017) is aimed at providing an effective framework to address the challenges facing agricultural sectors and to set the delivery targets for the departmental programmes from 2012 to 2017. The most recent policy directive to emerge from DAFF is the Agricultural Policy Action Plan (APAP), seeking to provide a long-term vision of the agricultural sector and more focused interventions in five-year rolling cycles. The NDP identifies agriculture as a primary economic activity in rural areas with the potential to create one million new jobs by 2030. The plan also proposes a number of approaches to land reform and its financing.

The Integrated Food Security Strategy (IFSS), endorsed by the South African Cabinet in 2002 after years of drafting, arguably failed due to an over-emphasis on agriculture (food availability) and inadequate institutional arrangements to align and coordinate related activities and programmes of government. The draft Food Security and Nutrition Policy for South Africa aimed to serve as a key pillar to achieving the objectives of the National Development Plan. The country’s Integrated Nutrition Strategy (INS) has three components: 1) a health facility-based component, 2) a community-based component and 3) a nutrition promotion component.

**Policy implementation challenges**

Existing policies and interventions that aim to alleviate food insecurity have been fragmented and are generally narrowly linked to the work of specific departments. These include agricultural credit and production programmes by DAFF, the National School Nutrition Programme by the Department of Basic Education, the Integrated Nutrition Programme by the Health Department, and the Department of Social Development’s “food for all” programme and “Zero Hunger” campaign. The challenge of addressing food insecurity and hunger in South Africa is widely recognised as inherently complex and the department largely responsible (i.e. DAFF) is poorly equipped, both administratively and conceptually, to deal with the interlinked priorities of poverty and hunger. One of the major reasons South Africa falls short of addressing food insecurity in a comprehensive manner is, in part, because food insecurity is not a technical issue that can be addressed by programmes run by existing departments. It requires a more coordinated approach that has both political will and resourcing, including elements of immediate and direct relief, and structural and institutional change that addresses distribution problems in the food system. The biggest problem with the implementation of current agricultural and food policies is the total absence of any coordination mechanism and the duplication of efforts and programmes. South Africa needs better coordinated and planned food security and nutrition interventions. Advocacy to raise the policy profile and social consensus for nutrition is essential. A collective vision to implement nutrition and health outcomes in agriculture is required, as identified in the NDP, Vision 2030.

**Policy instruments**

The main institutional and policy changes that have been implemented since 1994 in South Africa include the closure of marketing boards and the agricultural credit board, the abolition of certain
tax concessions and a reduction in direct input subsidies, the introduction of new labour legislation and the start of a land reform process, as well as research and development (R&D) services to emerging farmers. Trade tariffs have generally been reduced, and no export subsidies are applied, with the notable exception of the sugar industry. The agricultural sector is further excluded from carbon tax for the first 5 years of the programme.

**Way forward**

This report further presents the areas in need of further study, suggests an appropriate modeling framework to inform questions on the form sustainable agriculture could take in the country, and outlines policy processes and interventions needed to steer towards sustainable agriculture in support of green economic development.

One next step would be a comparative analysis between conventional and alternative systems based on empirical results from field trials around the country as well as the best available understanding of the current agricultural and food system in the country.

Further intervention would also be to invest in knowledge on multi-functional systems. The main options that need to be identified and tested in a South African context are:

- improving land and water management
- increasing yields on unproductive farms
- addressing barriers to entry for smaller-scale farmers
- shifting to degraded lands
- Reducing losses during distribution and storage in food value chains
- minimising post-consumption food waste
- shifting to different diets
- investing in research and innovation systems

Further empirical research is clearly required on alternative farming systems, as results worldwide point towards the importance of specific contexts in the success of alternative farming systems.

Lastly, a strong argument is made that one of the biggest challenges facing the implementation of current agricultural and food security policies – and therefore the success of sustainable agricultural and food systems in South Africa – is the absence of effective coordination mechanism that can align different responses across sectors. Further work will need to be focused on creating multisectoral social capital that promotes new local capacity for joint action.
1 Background and introduction

The world will need between 70% and 100% more food by 2050 to feed 9 billion or more people with less land, water and energy available, while having to cause much less degradation and pollution of natural support systems (Paolelli et al. 2011). In addition, agriculture will have to support further economic development, a situation which has been referred to as the “Great Balancing Act” (Searchinger et al. 2013). Current farming practices already use approximately 70% of global freshwater resources, 37% of total land area (excl. Antarctica) and is responsible for 24% of the world’s greenhouse gases (Searchinger et al. 2013; UNEP 2011; IAASTD, 2009). In South Africa arable land and permanent pastures account for 10% to 12% of land, while agriculture generates an estimated 1% of the country’s greenhouse gas emissions and uses 63% of its water resources (FAOSTAT 2013). Also, there are many signs of environmental degradation through land degradation (Botha & Fouche 2000; Oldeman 1992, cited in Reeves 1997; Bojo 1991) and soil erosion, over-abstraction of water, loss in biodiversity, ecosystem functionality and -resilience, as well as water pollution and increased vulnerability to climate change (IAASTD 2009).

South Africa has a debilitating water deficit with no surplus water available for future development (WWF 2010; Van der Merwe, 2008 quoted in Smith et al., 2010; Beukes, 2003). The country is water-stressed, allowing 1 034 m³ renewable fresh water per person, and is expected to become a water-scarce country with below 1 000 m³ per person within 15 years (Smith et al. 2010). The agricultural sector is one of the main water users in South Africa. It is therefore of utmost importance to identify and promote production systems with a high water-use efficiency.

Globally, current farming practices are also related to between 3 and 5 million cases of pesticide poisoning and over 40 000 deaths per year (UNEP 2011). South Africa is one of the largest importers of pesticides in Sub-Saharan Africa (Quinn et al. 2011), which poses local health and environmental risks (Thiere & Shulz 2004; London 2003). FAO data (FAOSTAT 2014) shows that in 2012, South Africa imported pesticides to the value of approximately US$ 341 million, which represented 95% of all pesticide imports into southern Africa and an increase of 206% from 1997. Pesticide exports were valued at US$ 253 million. With the intensification of agricultural production, particularly the strong growth in horticultural production (i.e. fruit, potatoes) and field crops such as soybean, has come an increase in the use of pesticides.

Another shortfall of current farming systems is that it does not provide adequate food security and nutrition to the global population. FAO (2013) estimates that approximately 870 million people globally are undernourished (in terms of calories and proteins), of which close to 100 million people are in the southern African Development Community (SADC) alone. According to this estimation there are no notable undernourished people in South Africa (De Wit & Midgley 2012). When other forms of nutritional deficiencies are included (e.g. vitamins and minerals) up to 3.7 billion people worldwide can be considered malnourished (Gomiero et al. 2011). In South Africa, at a household and individual level, the prevalence of food insecurity has decreased substantially since the mid-1990s, but an estimated 25% of South Africans are still food insecure (Labadarios et al. 2011). It is further estimated that 30–40% of food produced in the field is wasted throughout the food system (Gomiero et al. 2011), with South Africa being no exception (Oelofse and Nahmann 2012).
The agricultural sector plays an important role in providing livelihoods (i.e. an employment and economic base for households) worldwide. On the whole, this sector provides livelihoods for 40% of the world’s population (20% in South Africa). Over 70% of the poor live in rural areas and these people are directly dependent on agriculture as 90% of all farms worldwide have a size of less than 2ha (IAASTD 2011). By contrast, the average farm size in South Africa in 2007 was approximately 1400ha (Ramaila et al. 2011) and the agricultural sector is associated with a rapid decline in employment and a loss of income to workers with no clarity on whether it has played any role in the reduction of poverty in the country since 1995 (Bhorat et al. 2011).

It should be self-evident that the prevailing business-as-usual option is unsustainable. More people are consuming more food with less resources, more waste streams and an increasing impact on the ecosystems of the world. Sustainable agriculture has been proposed as an alternative to conventional farming systems (WRI 2014; Pretty 2014; Middelberg 2013; FAO 2013; UNEP 2011; Gomiero et al. 2011; NRC 2010; IAASTD 2009; Du Toit 2007; Bruinsma 2003), including the redesign of the global food system to achieve better food security and nutrition (FAO 2013). Sustainable agriculture, as presented in a synthesis by the IAASTD, an independent assessment by a group of 400 agricultural scientists and experts, is described as:

...a move away from short-term profit maximization towards ecologically sound farming that strives not for the highest possible, but for the highest sustainable yields, conserves soil and water, and enables smallholders in the global South to find a way out of poverty (Swissaid 2012).

Whether African agriculture needs to focus on smallholders only is still a matter of debate, although alternative labour-intensive smallholder sustainable agriculture is gaining much ground (Fanadzo 2012; Tshuma 2012; De Janvry 2010). The conditions under which a transition towards a more sustainable agriculture and food system would be successful is now a matter of intense debate and of utmost importance to South African agricultural and food policy in the immediate future.

Recognising that such a transition impacts on and will be impacted by broader global responses to natural resource and environmental constraints and the innovations such may bring, an explicit link has been made between sustainable agriculture and the broader transition towards a green economy (FAO 2012; UNEP 2011). The FAO’s Greening the Economy with Agriculture (GEA) initiative focuses on improving food and nutritional security, contributing to the quality of rural livelihoods, maintaining healthy ecosystems, respecting natural resource constraints in food production, and improving equity throughout the food supply chain. The central idea is to enhance agricultural productivity by managing the natural resource base in a more sustainable way, for example by diversifying crop rotations, using organic soil nutrients, reducing soil erosion and improving water-use efficiencies, making increased use of biological regulation functions (Ten Brink et al. 2012; UNEP 2011). Other studies present concepts of socio-economic improvement as a direct result of sustainable agriculture such as the creation of green jobs, achieving synergies between poverty alleviation and the green economy, the possibility of the green economy being an engine for development, and growing export markets for green and sustainable food (UNEP 2013; UNCTAD/UNDESA/UNEP 2012; Maia et al. 2011; UNEP/ILO 2008). In the aftermath of financial and debt crises around the globe and an increased realization of the intensity of ecological crises, economic growth and development models are clearly under scrutiny again.
In the South African context, the next step is to empirically test alternative forms of sustainable agriculture as central components of the green economy and to identify options that would deserve intervention. The first step in such a process, and also the objective of this report, is to document a baseline review on progress made on sustainable agriculture in South Africa. This baseline review includes information on alternative farming systems, food production and some consumption trends, food waste, job creation and livelihoods, food value chains, natural resource use and impacts on ecosystems, climate change, food security and nutrition as well as policies, strategies and governmental institutions available to support an agricultural and food transition towards a greener economy.

The results of this baseline review on sustainable agriculture in South Africa, as presented in this report, will inform the following:

- Further research needed on sustainable production systems, consumption trends, agricultural value chains, food security and nutrition, institutional models as well as policy instruments to affect desired change.
- Policy processes and engagement with institutions in the green economy.
- The development of a sustainable agriculture system dynamics model capable of simulating various options in the quest to achieve a more sustainable agriculture.

In Section 2 an introduction to sustainable agricultural systems is presented. The myriad of terminology in this field is defined and the need for a systems approach clarified. Section 3 gives a review of the progress made in sustainable farming systems, covering the major categories of field crops, horticulture and livestock. The focus is specifically on maize, citrus and extensive beef production. In Section 4 the scope is broadened to the entire sustainable agricultural system, reviewing the state of food production, some consumption trends and distribution, the quality of the system in relating to resource use and environmental impact, as well as the issue of food security and nutrition. Section 5 reviews key literature on comparative analysis between conventional and sustainable agricultural systems worldwide and present the main results of work that has been done in South Africa so far. Further research needs are identified and briefly discussed. In Section 6 a review of South African policies, laws and institutions to support sustainable agricultural systems is presented, identifying strengths and weaknesses and possible courses for policy and institutional action. Section 7 identifies areas in need of further study, presents suggestions on an appropriate modeling framework to inform questions on the form sustainable agriculture could take in the country, and outlines policy process and interventions needed to steer towards sustainable agriculture in support of economic development. Section 8 briefly summarizes and concludes.
2 Introduction to sustainable agricultural systems

2.1 Definitions

Sustainable agriculture is high on the global agenda with respect to issues such as reduced carbon footprint, conserving natural resources, climate change, and the ability to feed the continuous growing global population. What, however, is sustainable agriculture? Scientists, farmers and policy makers use different terms in trying to answer this question. It is neither desirable to increase the number of technical terms, nor to add to the confusion about the meaning of each term. Rather this report compares some of the important terms surrounding "sustainable agriculture" and synthesise important keywords (See Appendix 1 for a list of definitions and key words on sustainable agriculture).

The following general keywords and principles on the term sustainable agriculture are identified:

- More nature-based, that is mimicking nature and natural processes (e.g. biological regulation functions, integrated pest management, biodiversity, ecosystem health, agroforestry, enhance plant natural immunity, organic, permaculture, agro-ecology, no-tillage, natural balance, wildlife, “bio”, green manure and cover crops).

- Management systems are focused on achieving multiple objectives motivated by social, economic and ecological issues (e.g. systems thinking, holistic management, trans-disciplinary, multi-functional, multidimensional, mutualistic, complexity, relatedness, diversify, integration trees and livestock with cropping, diversity, process, gradual, environmental sociology, agro-ecology, human-ecological systems).

- Explicit inclusion of no humanly supplied inputs (e.g. Low External Input Sustainable Agriculture (LEISA), natural farming, agro-ecology, conservation, fertility farming).

- Site-specific crop management (e.g. precision farming, GIS-based farming, ecotype specific farming).

- In certain cases awareness of ethical, spiritual and worldview aspects related to farming (e.g. eco-ethics, biodynamic agriculture, transformation, anthroposophy, Farming God's Way, Foundations for Farming, stewardship, permaculture, earth care, regenerative agriculture, creation care, “back to Eden”).

The main emphasis is on fostering synergies between agricultural production, conservation and rural livelihoods.

For the purposes of this project we use categories developed in the literature on sustainable agriculture and start with the term Conservation Agriculture (CA). CA can be conceptualised as a stepwise and gradual process including production stages like No-Till (NT) and CA with high external- and with low external inputs. The most sustainable form of an agriculture production system is here portrayed as Organic Conservation Agriculture (OCA). OCA is based on the above-mentioned three CA-principles and enhanced with management systems and approaches (see Figure 1).
<table>
<thead>
<tr>
<th>Stage</th>
<th>Type of farming system</th>
<th>Minimum or reduced tillage</th>
<th>Conventional No tillage</th>
<th>Conventional Zero tillage</th>
<th>CAHEI</th>
<th>CALEI</th>
<th>Organic CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Conventional tillage</td>
<td>(Direct seeding equipment using tines). Production system lacks adequate soil cover and sound crop rotations.</td>
<td>(Direct seeding equipment using discs). Production system lacks adequate soil cover and sound crop rotations.</td>
<td>(NT or ZT using high quantities of external artificial inputs (i.e. fertiliser, herbicides, pesticides). Production system has adequate soil cover and sound crop rotations.</td>
<td>(NT or ZT using low quantities of external artificial inputs (i.e. fertiliser, herbicides, pesticides). Production system has adequate soil cover and sound crop rotations.</td>
<td>(ZT using no external artificial inputs (i.e. fertiliser, herbicides, pesticides). Production system has adequate soil cover and sound crop rotations.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Minimum or reduced tillage</td>
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<tr>
<td>3</td>
<td>Conventional No tillage</td>
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<td>4</td>
<td>Conventional Zero tillage</td>
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<tr>
<td>5</td>
<td>CAHEI</td>
<td></td>
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<tr>
<td>6</td>
<td>CALEI</td>
<td></td>
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</tr>
<tr>
<td>7</td>
<td>Organic CA</td>
<td></td>
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</tr>
</tbody>
</table>

**Figure 1** Schematic overview of farming systems towards sustainable agriculture

*Source: Based on Knot (2014)*

It has been argued that to achieve an OCA system several milestones should be reached: the use of artificial inputs should decrease, biological farming principles should increasingly be adopted, and cover and ley crops should be included (Knot 2014). The inclusion of legumes and cover crops (CC) into the crop rotation are beneficial not only for increased environmental quality, but also for increased net returns (Neto et al. 2010; Kelly et al. 1996; Zentner et al. 1992). A decrease in the use of synthetic fertiliser is possible to such an extent, that it can eventually be totally eliminated (Davis et al. 2012). The success of conservation tillage in organic farming hinges on the choice of crop rotation to ensure weed and disease control and nitrogen availability (Peigne et al. 2007 quoted in Bilalis et al. 2009; Bilalis et al. 2001). OCA incorporates management tools like precision farming, integrated pest management (IPM), improving soil quality by balancing soils through soil nutrient corrections, and promoting biological regulation functions for increased soil fertility and improved weed control. By having OCA at the heart of sustainable agriculture it also automatically draws in LEISA, cutting out synthetic inputs where possible, and moving towards agriculture based on healthy balanced soils. OCA has therefore been proposed as a conceptual alternative to conventional ways of farming. Organic farming is generally thought to be more environmentally benign than conventional farming (Tuck et al. 2014). Tuck et al. (2014) concluded in their global analysis of 94 organic studies (from before 2002 to 2011) that organic agriculture had a 34% higher biodiversity levels as compared to conventional agriculture.

However, organic agriculture is also characterised by decreased yields (Tuck et al. 2014) and higher prices compared to conventional agriculture. It appears that the organic produce market has not developed because the consumer is either not willing or unable to pay a premium for organic products, or are not necessarily aware of the benefits. The producer may not be ready or not interested in organic farming due to the dominance in economic interest over environmental interest (McDermott 2013). These issues raise valid questions pertaining to a strategy singularly focused on OCA to achieve food security objectives.
Conservation Agriculture refers to a farming system where three principles – minimum disturbance of the soil, year round soil cover and sound crop rotations including legumes – are applied simultaneously (Dumanski et al. 2006; Fowler 2004). The focus of CA is on producing good crops with healthy soils (Dumanski et al. 2006). CA encourages plant diversity, increased biological regulation functions (Djical et al. 2012), and risk minimisation. Cover crops, grown to protect and improve the soil quality, have been identified as probably being the main reason for the worldwide success of CA (Moyer 2011; Derpsch et al. 2010; Uchino et al. 2009; Steiner et al. 2001).

CA is not a standard model that can be applied everywhere. Knowler and Bradshaw (2007) concluded that CA should be tailored to the specific area in which it is applied. It is ecotype specific, context dependent, seasonally variable and a constant trade-off of simultaneously balancing adherence to various divergent sustainability objectives.

A major strength of CA is its step-like implementation by farmers of complementary, synergetic soil husbandry practices that build to a robust, cheaper, more productive and environmentally-friendly farming system (Dumanski et al. 2006). CA is gaining acceptance in many parts of the world as an alternative to conventional farming and organic agriculture (Dumanski et al. 2006). It has been described as the most cost-effective, sustainable and rapidly expanding crop production system in the world today (Fowler 2006). In theory, CA encourages a production system that is not only ecologically sustainable but also economically feasible and socially acceptable (Du Toit 2007; Dumanski et al. 2006). CA is based on optimising yields and profits and not on maximising yields per se while exploiting the soil and agro-ecosystem resources (Dumanski et al. 2006).

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### Figure 2

**Schematic presentation differentiating between Conservation Agriculture, Conservation Tillage and conventional tillage**

*Source:* Du Toit (2007)
Conservation tillage leaves at least 30% of crop residue on the soil surface. Reduced tillage, also referred to as minimum tillage, is defined as "...a tillage system which includes the minimum soil disturbance needed for crop production" (Derpsch 2001). It can also be defined as the minimum amount of soil disturbance which can be achieved using the equipment available to the farmer.

No-Till (NT) is defined as disturbing the soil as little as possible – only up to 20%–25% (Govaerts et al. 2009:98) – by using tine planters or combination tine and disc planters.

Govaerts et al. (2006:99) described the conversion from conventional tillage to NT and/or CA as a gradual or step-wise process with minimum tillage (MT), NT and CA (High External Inputs) as phases in the process. The MT phase may be skipped and various factors determine the length of each of the intermediate phases. Fowler (2004:10) observed that especially on "...medium- and large-scale farms, a primary limitation to the adoption of Zero Till...is the cost of the transition from conventional to No Till planters; Minimum Tillage can provide an affordable effective option to initiate the conversion to Conservation Agriculture". The length of over the phase in the process is determined by the availability of equipment and finances; level of know-how, information and management; and the level of (network) support from various stakeholders (Knot 2014).

In summary, the main differentiating factors in defining and comparing alternative farming systems over its various stages are the type of tillage technology used, the amount of soil cover left and the frequency of using multiple crops.

### 2.2 Sustainable agriculture: a systems approach

It was pointed out in the previous section that the achievement of multiple objectives is an important feature of sustainable agriculture. Ikerd (1993) further argued that the conventional, industrial production model of agriculture focuses on specialising, routinising and mechanising the agricultural production with the aim of maximising economic efficiency. Alternative sustainable agriculture models focus on diversifying, integrating and synthesising farming production units in complex relationships with the physical, biological and social environment, as well as with people and with institutions governing it. Sustainable agriculture therefore requires a holistic systems approach to farming, relying on knowledge-based development of whole farms and communities to address the myriad of socio-economic, ecological and political challenges in sustainable agriculture. Holistic approaches imply increased complexity, as suitable temporal, spatial and physical, often individual context-specific arrangements of interrelated system components such as markets, resources, products, inputs, people and processes need to be sought. The rewards in such a knowledge-based system are decreased social and environmental costs and the potential for synergism (Ikerd 1993: 157). Risks and rewards are seen to be sensitive to spatial arrangements (i.e. being ecotype specific) (Crookes et al. 2013; Ikerd 1993: 156).

A systems approach focuses on at least three aspects, namely the system’s function or purpose, the state and trends of components or elements within the system, and the nature and strength of structural and functional interrelationships between the components. Systems are managed for different purposes and on different levels. A farming system focuses on the resource base, enterprise and household livelihoods, while a food system focuses on the production and consumption of food. An agro-ecosystem, in turn, focuses on the production of food as well as
other socially valuable non-food goods and environmental services. A food security and nutrition system would focus on both food and nutrient intake interacting with individual health status (Ecker & Breisinger 2012: 3). For the purposes of this review and to inform a conceptual approach to the development of a systems model, the Sustainable Agriculture and Food System (SAFS) is defined here in the broadest sense and includes all these various overlapping subsystems (see Figure 3).

Figure 3  Sustainable Agriculture and Food System (SAFS) framework

Sources: Adapted from Ecker & Breisinger (2012) and Garnett & Godfray (2012)
3 The sustainability of farming systems in South Africa

3.1 Introduction

Organic agriculture is practiced in 164 countries, and more than 37.5 million ha of agricultural land are managed organically by 1.9 million farmers. The global sales of organic food and drink reached almost US$ 64 billion in 2012 (www.ifoam.org; Willer et al. 2013). Across Africa, there are slightly more than one million hectares of certified organic agricultural land (Willer et al. 2013) – approximately 3% of the world’s organic agricultural land. This roughly represents 0.1% of total agricultural land in Africa. Growth in organic agriculture in Africa has slowed in recent years, apparently following the global economic downturn post-2008 which has significantly impacted the European export markets. In Africa in 2011, more than a third (38% or 400 000ha) of all organic farmland was used for permanent crops, 14% was used for arable crops (150 000ha) and 6% (62 000ha) were grassland/grazing areas. The key permanent crop was coffee, followed by oilseeds (mainly sesame), olives and nuts. Most of this production (coffee, sesame) took place in East Africa, dominated by Uganda, Ethiopia, Tanzania and Sudan. Significant production areas (olives and nuts) were found in North Africa (Tunisia and Egypt). The majority of certified organic produce in Africa is destined for export market, mainly the European Union.

In southern Africa the country with the largest organic production area is South Africa. The area under organic agriculture has fluctuated between just under 42 000ha (2011, 0.04% of all agricultural land) and just under 60 000ha between 2008 and 2011, peaking at 59 562ha in 2009. In 2011, South Africa had 167 organic producers with 127 106ha of land being used for organic wild collection, thus giving a total of 169 052ha considered organic. Overall, adoption of this farming system has been extremely low, even in the context of African organic agriculture. Nevertheless, many resource-poor subsistence and smallholder farmers in South Africa practice organic farming because they are unable to afford agro-chemicals and are more likely to make use of traditional farming methods which can to a large degree be termed organic. These producers are not certified organic and thus the official numbers do not accurately represent the situation on the ground in this developing sub-sector.

In a market survey and forecast conducted by the African Organic Farming Foundation in 2005, Buffee estimated the value of the South African organic market to be R100 million across all categories of produce (Barrow 2006) (See Appendix 3 for main results of the survey). The main finding was that most of South Africa’s organic production is exported, mainly rooibos tea, citrus, sub-tropical fruit (e.g. avocados and bananas), fruit for processing or which keeps well (e.g. olives), specialty vegetables and berries, and herbs and wine. Very low volumes of fresh, highly-perishable produce such as stone and pome fruit are grown organically and almost all of this production is exported at very high prices to justify the costs.

The definitions and categories of sustainable agriculture to be used in this review are now established and the broad systems approach has been introduced. The question now is how far South Africa has already progressed towards a more sustainable agriculture and food system. In the next three sections, this question is addressed from the perspectives of field crops, horticulture and livestock production.
3.2 Sustainable farming with field crops

The production share of field crops have declined from a high of close to 50% at the end of the 1970s to just above 30% in the early 2000s (NDA 2006). The South African field crop production system still supplies most of the domestic need. Also, exports of cereals have declined rapidly between 1996 and 2005 (Sandrey & Vink 2008). According to the latest statistics, maize is still the second largest contributor (13.2%) to South Africa’s gross value of agricultural production of R180.36bn. Maize is produced by commercial farmers on approximately 2.5–2.75 million ha and by smallscale farmers on 300 000–350 000ha per annum. Bread and grains represent 27% of private expenditure on food in the country – after meat as the second highest component. Despite decreasing production shares relative to horticulture and animal products, field crops (notably maize) continues to play an important role in South African production and consumption.

Approximately 70% of South Africa’s cereals and 90% of its commercially grown maize is grown mainly rain-fed on the Highveld, an area known for its variability of yields that could be exacerbated by future climate change (Walker & Schulze 2008). Maize needs at least 450–600mm of water per season, mainly acquired through soil moisture reserves, and at maturity each plant would have consumed 250 litres of water (Du Plessis 2003). In 2009/2010 an estimated 16% of maize production in South Africa came from irrigated lands and increased irrigation has been proposed as an option to mitigate climate change (Fourie & Botha 2011; Akpula et al. 2008). The USDA (2013) estimated that irrigated maize in South Africa has more than doubled since 1995 and now occupies approximately 250 000ha of land. Both water scarcity and soil degradation are pressing issues. Commercial farmers, producing 95% of South Africa's food, are heavily dependent on NPK fertilisers to maintain yield levels. However, the high use of nitrogen-based synthetic fertiliser contributes to soil acidity. It is estimated that roughly 60% of the cropland area in South Africa is moderately to severely acidic in the topsoil and 15% of cropland is affected by subsoil acidity (Burger 2010).

One of the main causes of land degradation is intensive tillage (O’Dell et al. 2013) used during land preparation, planting, and weed and pest control. Tillage is often highlighted as the main cause of soil organic matter decline (Decker et al. 2011; Compton et al. 2010; Le Roux et al. 2007; Derpsch et al. 2006; Mills & Fey 2003) and the type of tillage used heavily affects the vulnerability of soils to water and wind erosion (Du Plessis 2003). The factors leading to the loss of soil organic matter and the related decline in soil quality can probably be attributed to erosion and vegetation removal (Compton et al. 2010; Mills & Fey 2003). According to Du Preez et al. (2011), vegetation removal is the result of overgrazing and burning. Conventional tillage contributes to increased erosion (Laker 2004; Mills & Fey 2004) and therefore, indirectly, to the decline of soil organic matter. Land degradation is one of the major challenges to sustainable agriculture in South Africa (Du Preez et al. 2011).

Increased water-use efficiency can be achieved through better soil cover. Cover crops have been identified as probably the main reason for the success of CA (Moyer 2011; Derpsch et al. 2010; Uchino et al. 2009; Pieri et al. 2002; Steiner et al. 2001). Also, permanent soil cover with a thick layer of mulch has been a key factor for success in NT in Latin America (Derpsch 2001). Cover crop trials (i.e. inter-seeded into maize) have been conducted in the eastern Free State with good results. (See Knot (2014) for more details on soil wetness and water-use efficiency under NT cover cropping.) It must, however, be noted that double cropping (i.e. two crops in one year on the same land) under conventional farming is not possible in the eastern Free State (and probably
the whole Highveld maize production region) and is locally referred to as ‘bankrupt farming’ (Knot 2014: 110). Cover crops have the further benefit of suppressing weeds, one of the main challenges for sustainable farming.

Commercial farmers in South Africa have already started reducing tillage on their farms, mainly due to rising fuel prices. For example, farmers will plough every second or third year rather than annually. There is also a shift towards secondary tillage where mouldboard ploughing and deep ripping is replaced by chisel ploughing, shallow ripping and multiple disking. Conventional farming is associated with bare fallow as part of the crop rotation system to improve water harvesting and break pest cycles; the use and need of bare fallow is a contested practice under more sustainable farming systems (McNee et al. 2008; Sooby et al. 1997).

Conservation tillage (CT) and No-Tillage (NT) are gaining more acceptance in South Africa. Table 1 shows figures from 2004 (the most recent update available). An estimated 35% and 9% of total hectares in South Africa was under CT (mainly RT/MT) and NT respectively in 2004. For CT the Free State led with 41% of the national total, followed by North-West (26%) and Mpumalanga (13%). For NT the Free State led with 31% of the national total, followed by the Western Cape (22%) and Mpumalanga (20%). These figures are not recent and can only be used as a rough indication.
Table 1  Estimated ha under CT and NT practices – SA (2003/04)

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Western Cape</th>
<th>Eastern Cape</th>
<th>Limpopo</th>
<th>Northern Cape</th>
<th>KwaZulu-Natal</th>
<th>Gauteng</th>
<th>Free State</th>
<th>Mpumalanga</th>
<th>North West</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hectares</strong></td>
<td>4,402,255</td>
<td>452,110</td>
<td>22,925</td>
<td>85,600</td>
<td>110,450</td>
<td>101,350</td>
<td>133,500</td>
<td>1,590,900</td>
<td>694,650</td>
<td>1,210,770</td>
</tr>
<tr>
<td><strong>Conservation</strong></td>
<td></td>
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<td><strong>Tillage:</strong></td>
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<tr>
<td>Provincial</td>
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<td></td>
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</tr>
<tr>
<td>Percentage</td>
<td>40.7%</td>
<td>19.3%</td>
<td>19.9%</td>
<td>19.6%</td>
<td>44.1%</td>
<td>24.6%</td>
<td>39.2%</td>
<td>29.1%</td>
<td>32.4%</td>
<td></td>
</tr>
<tr>
<td>Provincial Hectares</td>
<td>1,522,718</td>
<td>184,009</td>
<td>4,425</td>
<td>17,034</td>
<td>21,648</td>
<td>44,695</td>
<td>32,841</td>
<td>623,633</td>
<td>202,143</td>
<td>392,289</td>
</tr>
<tr>
<td>National Percentage</td>
<td>34.6%</td>
<td>12.1%</td>
<td>0.3%</td>
<td>1.1%</td>
<td>1.4%</td>
<td>2.9%</td>
<td>2.2%</td>
<td>41.0%</td>
<td>13.3%</td>
<td>25.8%</td>
</tr>
<tr>
<td><strong>No-Tillage:</strong></td>
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<tr>
<td>Percentage</td>
<td>18.1%</td>
<td>3.4%</td>
<td>5%</td>
<td>5.3%</td>
<td>17.9%</td>
<td>7.4%</td>
<td>7.4%</td>
<td>10.9%</td>
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<tr>
<td>Provincial Hectares</td>
<td>377,169</td>
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<td>779</td>
<td>4,280</td>
<td>5,854</td>
<td>18,142</td>
<td>9,879</td>
<td>117,727</td>
<td>75,717</td>
<td>62,960</td>
</tr>
<tr>
<td>National Percentage</td>
<td>8.6%</td>
<td>21.7%</td>
<td>0.2%</td>
<td>1.1%</td>
<td>1.6%</td>
<td>4.8%</td>
<td>2.6%</td>
<td>31.2%</td>
<td>20.1%</td>
<td>16.7%</td>
</tr>
</tbody>
</table>

**Source:** Hittersay (2004, as cited in Fowler 2004)

Several agencies and research stations (e.g. Elsenburg, Western Cape NT Association, Cedara and KZN NT Club) are promoting CA in South Africa. Recently a group of about sixty divergent CA stakeholders (from the Agricultural Research Council (ARC); provincial departments of agriculture; farmers; farmers’ organisations/organised agriculture; NGOs; and universities) conveyed and attended a meeting to discuss progress in CA (Smith et al. 2010) and made the following observations (ARC 2010):

- There is a need to aim at a forum for the branding of CA so that everybody talks about the same thing. All should aim for the same goal, as they will then have the foundation to develop policies. There is a need to consolidate their position, and then work towards a strategy to create a policy.

- When farmers demonstrate success the politicians will listen. The focus must be on farmers first.

- It needs to be demonstrated that CA can reduce greenhouse gases and affect climate change positively.

- The opinion was expressed that prolonged and inappropriate research by soil scientists had made negative, rather than positive, contributions to the adoption of CA in South Africa. This opinion did not go uncontested, and a balance between understanding and implementation needs to be maintained.

- The challenge is to come up with mechanisms on how research results will reach the people who assist the end-users.

- There is a need to look critically at the marketing of CA and farmers must be mobilised to assist in the promotion and marketing.

These observations call for clarification of CA definitions, demonstration of success and well-researched evidence in support of CA, effective engagement of CA products in markets, and lobbying of government institutions.

The current interest in CA is informed by research efforts to some extent, although it is small in scope and mainly focused on limited objectives in specific cases. A summary of CA-related
research is included in Appendix 2. CA has been promoted by the national government, the FAO, private agricultural organisations, some non-governmental organisations, NT clubs, task forces and NT associations. However, to date there is no synthesis publication that summarises the promotional work and research undertaken on CA in South Africa so far. The FAO-driven National CA task force is trying to coordinate and collate CA/NT information and a comprehensive document is Smith et al. (2010), but this effort together with that of the ARC is more geared towards agricultural smallholder production. Grain SA (2013) has also recently started to coordinate, mitigate and advocate NT/CA among commercial farmers in SA.

There is clearly a need to research, demonstrate and communicate the actual results of CA in a South African market and policy context. More empirical research is required to compare the impacts of conventional and alternative farming systems (defined over various production stages, with specific reference to the type of tillage technology used, the amount of soil cover, and the frequency of using multiple crops) on factors such as water-use efficiency, land degradation and soil quality, and vulnerability to climatic changes. The viability of alternative farming systems across different groups of farmers (e.g. commercial, smallscale) also needs further research.

3.3 Sustainable farming in horticulture

The horticulture sub-sector in South Africa plays a significant role in the agricultural economy due to a strong export focus and its labour-absorbing ability. Grapes, apples, potatoes, oranges, tomatoes, pears and bananas feature prominently in the top 20 commodities in terms of production. According to the 2012/2013 export values (DAFF 2014), the most important agricultural export products were citrus fruit (R7 981 million), wine (R6 965 million), maize (R5 294 million), apples, pears and quinces (R5 172 million), and grapes (R4 576 million). Oranges alone account for a higher export value than all other horticultural export commodities (individually) except wine. Processed fruits and nuts, and beverages such as apple and orange concentrate also make substantial contributions to national exports. Gross farming income from horticulture has shown significant growth over the last 25 years, from R4.5 billion in 1993 to R29.6 billion in 2009, an increase of 560% (Statistics South Africa 2011a). In 2012, gross farming income was estimated at R32.3 billion, increasing by 9% from 2011 to 2012 (Statistics South Africa 2012). The contribution of horticulture to overall agricultural farming income is 25%.

This study focuses on citrus production since it is the most important national horticultural export crop (apart from wine), it is grown widely across the country in diverse agro-ecological production areas, and it has good potential for all farming systems, from commercial to smallholder and even subsistence farming.

Citrus orchards are planted in South Africa and Swaziland on 60 355ha of farmland (see Table 2) (CGA 2012), with oranges representing by far the biggest variety. The industry is centered around Limpopo and Eastern Cape Provinces (see Table 3), with the Western Cape contributing mainly to the production of soft citrus and lemons, which require slightly cooler climates.
### Table 2  Citrus orchards in South Africa and Swaziland by variety

<table>
<thead>
<tr>
<th>Variety</th>
<th>Hectares</th>
<th>% of area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valencia orange</td>
<td>25 398</td>
<td>42</td>
</tr>
<tr>
<td>Navel orange</td>
<td>14 832</td>
<td>24</td>
</tr>
<tr>
<td>Grapefruit</td>
<td>9477</td>
<td>16</td>
</tr>
<tr>
<td>Soft citrus</td>
<td>5200</td>
<td>9</td>
</tr>
<tr>
<td>Lemon</td>
<td>4726</td>
<td>8</td>
</tr>
<tr>
<td>Midseason</td>
<td>636</td>
<td>1</td>
</tr>
<tr>
<td>Pummelo</td>
<td>87</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60 355</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Source: Adapted from CGA (2012)*

### Table 3  Citrus orchards in South Africa and Swaziland, by province

<table>
<thead>
<tr>
<th>Province</th>
<th>Hectares</th>
<th>% of area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limpopo</td>
<td>25 674</td>
<td>42</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td>12 508</td>
<td>21</td>
</tr>
<tr>
<td>Western Cape</td>
<td>8961</td>
<td>15</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>6817</td>
<td>11</td>
</tr>
<tr>
<td>KZN</td>
<td>3405</td>
<td>6</td>
</tr>
<tr>
<td>Swaziland</td>
<td>1774</td>
<td>3</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>1215</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>60 355</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

*Source: Adapted from CGA (2012)*

In terms of gross value, the citrus industry is the third largest horticultural industry after deciduous fruits and vegetables (DAFF 2012b). During the 2010/2011 production season the industry contributed R6.9 billion to the total gross value of South Africa’s agricultural production. This represented 19% of the total gross value (R36.4 billion) of horticulture during the same period. The citrus industry is also an important foreign exchange earner and comprises four broad categories, namely oranges, easy peelers (soft citrus), grapefruit, and lemons and limes. The citrus industry is labour-intensive, employing more than 100 000 people with large numbers of workers in the orchards and packing houses (DAFF 2012b). Furthermore, an unspecified number of people are employed throughout the supply chain for services such as transport, port handling and allied services. It is estimated that more than a million households depend on the South African citrus industry for their livelihood.

Orange exports have grown to between 900 000 and 1 million tons in 2010/2011 (DAFF 2014; CGA 2012). Grapefruit exports are also important at approximately 200 000 tons, while lemon exports have grown to well around 160 000 tons in 2010/2011. In total, 70% of citrus production is exported, 22% is marketed locally, and 8% is processed. Both local and international prices have increased steadily over the last 10 years. South Africa ranks 13th in world for fresh citrus production (according to tons), 3rd in world for fresh oranges exported (after Spain and Turkey), and 3rd in world for fresh grapefruit exported.
Although the South African horticultural industries have a strong export focus, they also supply most of the local demand for fresh and processed fruit, vegetables, tea and flowers. Farming systems are dominantly conventional, relying on intensive management and inputs of agrochemicals (although mostly with Integrated Pest Management). This has been justified both from a profitability point of view and because of the strict phytosanitary requirements of export markets. Efforts to reduce chemical inputs and increase efficiencies of inputs have been driven by the demands of the export market and input price concerns (mainly market access and profitability) rather than ecological/health concerns (Urquhart 1999).

Horticulture is further sensitive to climatic and environmental conditions, notably temperature, water and soil. Fruit and vegetable crops thrive under warm temperate or sub-tropical climates, free of frost during the production season, and for some crops such as apples and berries there is also a requirement for colder temperatures (chilling) during the dormant season. Commercial production of fruit crops is very water-intensive and almost entirely under irrigation, although rainfall contributes to water requirements in areas with higher rainfall such as Mpumalanga, parts of Limpopo and the Eastern Cape. In the winter rainfall region of the Western and Northern Cape, irrigation water is provided in summer by large government-owned dams, smaller private farm dams, and abstraction from rivers. Soil requirements vary, but in general fruit crops require loamy soils of sufficient depth with good drainage.

Much of the deciduous horticultural production of the Western Cape takes place in soils of poor fertility, and regular fertilisation is standard practice in order to achieve consistently high yield and quality. Citrus and other sub-tropical fruits are usually grown in areas of higher fertility, but commercial production also includes fertilisation. Within the horticulture sub-sector, fertiliser use varies (See Table 4) (FAO 2005). Citrus crops have a slightly lower requirement than deciduous crops but cover a larger area, with both representing 2% of national fertiliser use in tons. Sub-tropical fruit, vegetables and potatoes require much higher rates of application, and the latter two represent 10% of national fertiliser use because more extensive areas are under cultivation. Other inputs include herbicides, pesticides, fungicides and rest breaking agents (for apples). For an average-bearing apple orchard, costs of agro-chemicals per annum amount to approximately 7.9% of the total budget per hectare (Hortgro 2012).
Table 4  Fertiliser use in horticulture

<table>
<thead>
<tr>
<th>Crop</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>N</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Total ('1000 tons)</th>
<th>%*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rate (kg/ha)</td>
<td></td>
<td></td>
<td>Total ('1000 tons)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Citrus</td>
<td>80</td>
<td>35</td>
<td>60</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Sub-tropical</td>
<td>180</td>
<td>57</td>
<td>240</td>
<td>9</td>
<td>3</td>
<td>12</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>fruit/nuts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vines</td>
<td>50</td>
<td>36</td>
<td>24</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Deciduous fruit</td>
<td>110</td>
<td>159</td>
<td>83</td>
<td>6</td>
<td>2</td>
<td>4</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Vegetables</td>
<td>170</td>
<td>159</td>
<td>120</td>
<td>16</td>
<td>15</td>
<td>11</td>
<td>42</td>
<td>6</td>
</tr>
<tr>
<td>Potatoes</td>
<td>170</td>
<td>160</td>
<td>120</td>
<td>9</td>
<td>8</td>
<td>6</td>
<td>23</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Adapted from FAO (2005)

Note: *Percentage calculated for fertiliser consumption by all crops (field, industrial, horticultural)

The principles of sustainable farming apply equally to fruit production as they do to field crops and livestock. There is a need to lower the carbon and the water footprints of production and the post-harvest chain, to improve the management of soils, to further reduce and eliminate the use of expensive and harmful chemical inputs, but still to maintain and increase production and quality levels, profitability and employment. Section 2 of this review discussed the merits of Conservation Agriculture. In fruit farming, only two of the principles of CA are applicable to some degree: 1) minimum or no disturbance of the soil and 2) permanent soil cover. Perennial crops such as orchards, with a productive life-span of at least 25–30 years, do not allow for the principle of crop rotations, which excludes the potential benefits of this practice particularly with respect to disease, pest and fertility management. However, the fruit industries do, to some extent, promote practices aligning with the first two principles.

Orchard soils are prepared, including tillage and sometimes fumigation, before the establishment of the new orchard. Thereafter, there is generally no further disturbance of the soil. However, soil compaction from excessive tractor usage between rows is avoided under current best practice guidelines. Some farmers use mulch such as straw (Liu et al. 2014), wood chips and plant compost, and more recently some have experimented with vermin-compost. Mulches are reapplied every three years or so. The use of permanent soil cover in orchards can complicate the control of pests (e.g. woolly apple aphid) and diseases, since they can ‘hide’ in the cover. There remains a tendency by some farmers to prefer a “clean” orchard, and mulch is seen as an additional cost and is not always readily available in large volumes.

The debate around “soil health” and biological approaches to soil management has been ongoing in the fruit industries for many years, with conflicting or inconclusive research results, and little agreement on what this is and how to achieve it. There is some interest in the role and benefits of the arbuscular mycorrhizal (AM) fungus with evidence that it contributes to soil and root health (Jeffries et al. 2003). The fungus is present in most soils and capable of forming associations with the root systems of a great majority of vascular plant species where it acts as a bioregulator and protector, and facilitates the uptake of mineral nutrients. A range of “soil health” practices have been promoted and applied on farms; some claim positive results, but there is little scientific and consistent evidence for the benefits under South African conditions. There does not exist a useful
summary on this topic and farmers generally decide for themselves how to approach it. Part of the problem is the lack of long-term transdisciplinary research trials which are needed to better understand the complex living soil system. There is also a lack of agreement on “soil health” indicators.

Another area of concern in conventional citrus production is the high reliance on water for irrigation. Water resources in many of South Africa’s core horticultural production areas are coming under increasing pressure from other major users (power generation, mining, industry, urbanisation) and the growing population in need of water-based services. For example, the intensive fruit and wine production within the Berg River Catchment in the Western Cape taps into a water supply system which is increasingly needed for the City of Cape Town (Midgley et al. 2014), with allocations to agriculture at risk of being re-allocated to other demands. In addition, intensive industrialised agriculture, together with other drivers, has contributed to the deterioration of water quality in parts of the Catchment. This poses a risk of produce being excluded from core export markets if quality thresholds are exceeded for fresh produce production. Complexity of the belowground system is increased by the practice of irrigation (Naor 2006). All commercial orchards in South Africa are irrigated, and rates depend on various factors such as fruit type, rootstock, orchard age, row spacing and orchard density, soil characteristics, and local climate. Currently, water use of apple trees in a commercial orchard is approximately 9 000 to 10 000 m$^3$/ha/annum (some farmers aim for 8 000 m$^3$/ha/annum), with a mean yield of 50–80 tons/ha; this amounts to between 150 (best case) and 250 (average) m$^3$/ton (Baleta & Pegram 2014; Mekonnen & Hoekstra 2011). A study by Volschenk et al. (2003) on apples showed that farmers tend to over-irrigate their orchards, mainly as a result of a lack of objective tools to schedule irrigation.

Figure 4 shows that horticultural crops consume considerable volumes of water in South Africa. Citrus production alone depends on approximately 500 million m$^3$ of irrigation (blue) water per annum, much of it in Limpopo and the Western Cape where water resources are constrained. Promotion and adoption of practices to increase water-use efficiency and better use of scarce water resources are needed to achieve greater sustainability. This is expressed or measured through indicators such as water-use efficiency (WUE), precipitation-use efficiency (PUE) (Bennie & Hensley 2001) or rain-use efficiency (RUE) (Snyman 2004). Efficient irrigation

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**Figure 4** Water footprint (in m$^3$ per annum) of the South African horticultural sector

*Source: Baleta and Pegram (2014)*

Note: ‘Green’ water refers to water use from rainfall and ‘blue’ water refers to irrigation water.
management also increases economic returns through water savings, improved fruit quality, reduced leaching of fertilisers and other agro-chemicals (whose costs are rising), and lower pumping costs (Dzikiti et al. unpublished). As irrigation methods improve, water becomes scarcer, and pumping costs escalate, growers are beginning to adopt precise irrigation scheduling technologies (Annandale et al. 2011). Precision irrigation scheduling involves withholding water at key periods in fruit development, and is now increasingly used as a tool for manipulating fruit quality given that excessive irrigation reduces fruit quality.

Precision agriculture has been adopted by some fruit and wine producers in an effort to increase efficiencies of inputs such as fertilisers and irrigation and to optimise crop growth and product quality. A demonstration project named FruitLook was launched in 2011 with the purpose of using satellite observations to assist grape and fruit farmers in optimising their irrigation and fertilisation schedules on a weekly basis (www.fruitlook.co.za). The web-based system provides information on nine parameters per plot, such as evapotranspiration deficit, crop factor, biomass growth, biomass water-use efficiency and nitrogen content. The pilot no-cost FruitLook service was funded by the Western Cape Department of Agriculture, with support of the Department of Agriculture, Forestry and Fisheries, HortGro and the Integrated Applications Promotion programme of the European Space Agency (ESA). FruitLook is now being commercialised and promoted by industry bodies. The current users are primarily table grape and wine farms, as well as some deciduous fruit farms. It remains to be seen whether or adoption rates of the commercial programme increase, and if emerging commercial wine and fruit farmers join the service. It is remains uncertain whether smallholder farmers will take an interest or be able to access this technology.

Another example of precision farming in horticulture relates to the use of regular detailed soil and leaf mineral analyses which are the basis of precise fertiliser recommendations. Most commercial farmers make use of these services provided by local laboratories. Similarly, farmers are investing in soil moisture monitoring technologies to guide orchard-specific irrigation scheduling.

In spite of these efforts, from a production point of view, the soil component of sustainable farming (cover, soil biodiversity, etc.) cannot be regarded as satisfactory within the mainstream horticultural sector. Soil and water resources are still impacted negatively by intensive horticulture and further interventions are required towards a more sustainable system.

A further important consideration in fruit farming is weed control, both in the row of trees and in the alley between the rows. Numerous weed control strategies are used, often including herbicides, mechanical practices such as mowing, or cover crops. Cover crops, however, are not popular since they are seen to compete with the fine root system and nutrient/water uptake in the upper soil layer.

Another aspect is the dosage and frequency of use of agro-chemical sprays. The fruit industries of South Africa have all adopted and promoted the “Integrated Pest Management” (IPM) approach as discussed in Box 1. In general, waste management and pollution control are dealt with by the good agricultural practices (GlobalGAP), and hazard risk management (HACPP) guidelines and other certification schemes.
Box 1  Integrated Pest Management (IPM)

Despite apparently solid conceptual grounding and substantial promotion by scientists, activists and policy-makers, IPM has a relatively poor adoption record in many parts of the world (World Bank 2005; Orr 2003; Morse & Buhler 1997). This is borne out by monitoring of pesticide use patterns globally. Pesticide expenditures are accounting for a growing share of total expenditures of farm production inputs, increasing from 3–4% in the 1950s to 7–8% in the 1990s in the USA (Ehler 2006). Pesticide use has also increased in many developing countries. Reasons include research weaknesses, outreach weaknesses, IPM weaknesses, farmer weaknesses, pesticide industry interference, and weak adoption incentives (Parsa et al. 2014). As a group, developing-country respondents rate “IPM requires collective action within a farming community” as their top obstacle to IPM adoption (Parsa et al. 2014).

This indicates a need for group action, and appears to be possible (e.g. in South Africa) where participation in international trade requires adherence to strict food safety rules and a response to the relentless drive towards residue-free fresh produce by some recipient markets. Excessive pesticide residues are among the major reasons for rejection of shipments of agricultural products. In order to comply with international food safety standards (public and particularly private standards), many exporting countries (including South Africa) have upgraded, or are in the process of upgrading their policies, regulations, enforcement and infrastructure on pest management.

The citrus and deciduous fruit (tree fruit and vines) industries of South Africa actively promote IMP as their industry management practice (Charleston et al. 2013; Urquhart 1999) and it is also increasingly being promoted for vegetable production, particularly where produce is exported (Kerr 2012). Statistics are not readily available, but it is likely that the majority of commercial export-orientated farmers use this management system at least in some form.

In South Africa, the adoption of IPM in the commercial citrus industry has been driven by three major factors (Urquhart 1999):

- requirements of the international market, particularly with respect to pesticide residue regulations and criteria of buyers
- increasing resistance to pesticides on the part of pests
- environmental responsibility on the part of growers

Of these three causative factors, environmental responsibility seems to be the least significant, and the bottom line appears to be economic. It is more about retaining a share in the market and keeping in business, rather than any great awareness on the part of growers in general as to possible economic efficiencies achievable through adoption of IPM approaches. There is a clear feeling that growers have been forced into change, rather than moving towards IPM methods from any moral obligation.

An IPM research group is based at Stellenbosch University and applied research includes the use of biological control agents for managing arthropod pests (Malan et al. 2011), postharvest control methods, and optimisation of the sterile insect technique (SIT). This enables cost-effective decisions to be made about when and where to focus control efforts and therefore sustainably manage pests while reducing the use of synthetic chemicals.

The SA horticultural industries have development programmes for emerging farmers from disadvantaged groups to have access to information, training and extension as for established commercial farmers. However, the penetration and efficacy of IPM for small-scale horticultural farmers in SA is not known from desktop research – direct communications and interviews with stakeholders will be necessary to gauge this and source data. It is likely that those small-scale and emerging farmers with access to the export market are using this approach with the support of the commodity groups (for extension and assistance with certification processes), but those supplying communities and local markets and not connected to the commodity group are less likely to be using this approach. The likelihood of IPM adoption is high where there is strong regulatory enforcement or special markets for pesticide free products (World Bank 2005). The European Union is moving strongly towards the goal of residue-free produce – this is seen by most South African producers as not currently achievable given the high pest pressure, specific pest problems which are difficult to manage, and lack of “softer” alternatives to some widely used conventional chemicals. The strategy is thus to seek and move towards alternative markets which do not have such ambitions.

With regards to the reduction of greenhouse gases, recent efforts focused on measuring the carbon footprint of fruit and wine production (CCC 2014) and benchmarking the carbon
emissions of each major commodity have shown what the major contributions to emissions are. These are: grid-supplied electricity (for the pumping of water and for cold storage), followed by fuel (mainly diesel consumption on-farm and for transport), nitrogen-based synthetic fertilisers and virgin packaging materials. Options for the reduction in carbon-intensive energy use are under investigation by a number of researchers and industry practitioners. Energy audits and subsequent interventions have delivered significant savings. The most common approach is switching to renewable energy for pumping, storage and packaging, as well as the installation of variable speed drives for irrigation.

There are several barriers towards adopting more sustainable practices in horticulture. Many smaller farming units are becoming unprofitable because of the administrative and cost pressures. Organic fruit and vegetable producers and exporters face the following additional unique constraints (Beltrán-Esteve et al. 2012; Ndou 2012; Neeson 2008; FAO 2007):

- The costliest items in horticultural farming are always variable inputs (i.e. irrigation water, fertilisers and labour) and variable costs per hectare are higher in organic farms. Organic manure is more expensive and difficult to obtain than chemical fertilisers and must be used in greater quantities to meet the requirements of adult orchards. Also, organic orchards are substantially more labour-demanding than conventional ones.

- It is difficult to isolate organic fruit or wine farms from intensive conventional farms in the same area. This can cause contamination from agro-chemicals and interference in organic pest and disease management practices.

- The demand for organic produce has slowed down and is sensitive to both economic cycles and the first-world drive to source locally grown organic food. The small organic market is vulnerable to over-supply and declining price premiums. Contractual arrangements with importers become important for risk management. In South Africa, premiums for organic produce on the local market are small and constantly under pressure.

- Unstable land tenure systems may deter farmers from converting to organic cultivation, since a transition period of two years is often required before products can be sold as organic. Farmers consider this period of low yields and prices as an investment which is worth making only if they can keep the land long enough to benefit from higher prices once they have obtained certification.
3.4 Sustainable livestock production

The majority of the world’s agricultural lands (68.7%) are used for grazing (FAO 2010 quoted in OFA 2012). Livestock production in the southern Africa region has been on the increase since 2008. An estimated population of 61.8 million cattle is found in this region of which 75% are in the communal areas (Muchenje et al. n.d.).

Livestock is the largest agricultural sub-sector in South Africa, contributing approximately 25–30% to the total agricultural output per annum (Musemwa et al. 2013). The area involved in cattle, sheep and goat farming in South Africa represents 53% of all agricultural land. Rainfall is a major driver of national herd size, notably cattle (DAFF 2014), but there are also concerns of the effects of overgrazing on soil characteristics (Snyman & du Preez 2005) as well as bush encroachment and the available of palatable grass species (Hudak 1999). In all cases, beef production is by far the most water-intensive food using a global average of 15 400 m$^3$/ton produced (Mekonnen & Hoekstra 2010), with some notable variation between countries and production systems.

In the case of poultry, 988 million broilers were slaughtered (1.8 million tons) in South Africa in 2012/2013, the egg industry counted 24.5 million layers producing 630 million dozens at an average producer price of approximately R10/doz. Almost 60% of all meat consumed in South Africa is poultry, at a rate of 38 kg/pp/pa in 2012/2013. Consumption of other red meats has also increased to 889 Mt of beef, 159 Mt of mutton and 246 Mt of pork in 2012/2013.

There are around 14 million cattle in the country (80% of which are beef and 20% dairy) 24 million sheep, 6 million goats and 1.6 million pigs. Around 60% of cattle is owned by an estimated 50 000 commercial farmers and 40% by 240 000 emerging farmers and 3 million subsistence/communal farmers (Webb 2013; NDA 2012). Almost 2.2 million cattle are commercially slaughtered per annum, as well as 4.6 million sheep and lambs and 2.5 million pigs. Total slaughtering of cattle, including emerging and communal farmers, are close to 2.9 million (NDA 2012) and per capita consumption is around 16.6 kg/pp/pa (down from a peak of 26 kg/pp/pa in the late 1970s). South Africa is a net importer of beef as consumption exceeded production in most recent years. The beef exports that do occur are now mostly to other African countries, most notably to Mozambique (NDA 2012) (see Table 5 for figures on the number of cattle slaughtered, beef production and consumption).
The low number of cattle slaughtered by emerging and communal farmers does raise the question on the increasing role of feedlots in commercial farming and the potential scope of increased productivity of communal farmers. Feedlots are used to fatten animals quickly and now account for 75% of all beef production in South Africa. Feedlot cattle show higher profits than conventional or organic pasture cattle (Esterhuizen et al. 2008). However, with this intensification comes other problems. One issue is animal welfare as 70–75% of cattle spent 33% of their lives (90–110 days) in crowded and stressful environments (WWF 2010a). Another issue is that penicillin and vaccinations are used, as feedlots are more prone to disease and contamination. It is further pointed out that food quality may decline with the use growth hormones in feedlots (Pickover 2005: 150). It has been noted that feedlot-fed cattle in Australia produced lower total greenhouse gas emissions than grass-fed cattle, but much more water is used per volume of meat produced (WWF 2010a).

Feedlots are not the only option though. Certain breeds do compare favourably with established breeds with regards to productive performance and meat quality on natural pastures (Muchenje et al. 2008) and producing meat with lower saturated fatty acids and more vitamins on rangelands (Mapiye et al. 2007). Muchenje et al. (2009) calls for further meat quality studies in low input production systems.

Cattle productivity in the smallholder sector, however, is declining due to the prevalence of diseases and parasites, a lack of feed resources, and poor breeding and marketing management (Musemwa et al. 2008). Market off-take rates in the communal cattle production system of targeted areas in the Eastern Cape were 12%, compared to 25% in the commercial sector (Musemwa et al. 2010). In order to achieve sustainable production, Musemwa et al. (2008) recommends improved attention on communal beef farming with increased attention on marketing, and not only focusing on production constraints.

Cattle under commercial systems still spend considerable time outside of feedlots and are either directly or indirectly grass-fed. Direct grazing refers to veld, pastures and wasteland (e.g. koppies). Indirect grazing refers to supplementing (winter) feeding with grass bales (i.e. surplus harvested during summer periods). Beef cattle also feed on green manure crops. The Highveld areas of South Africa produce predominantly fall-seeded winter crops like oats, rye and radishes. Beef cattle are also fed on grain-based silage (i.e. maize or fodder sorghum). Complementary
feeding is often done in the form of salt and nutrient licks. Mixed farming systems traditionally feed cattle on crop residues during the winter months. This acts as a barrier for CV farmers to convert to NT and NT farmers to upgrade to CA, given the need to leave soil cover. Low rainfall areas (400–600mm) also use grazing strategies such as feeding field crops to livestock, referred to as "standing feed". Increased drought tolerant varieties like grain sorghum are used. Some farmers make feed pellets from own-produced crops to sustain cattle during the limited and non-producing winter months. Grass pastures need to be top-dressed with synthetic N fertilisers in order to be productive, while legume-based pastures eliminate annual top-dressing of N fertilisers. Fertilisers contain large direct and indirect loads to the environment (Knot 2014).

The extensive grazing system of South African producers is often referred to as under-stocked and overgrazed. This implies that cattle are allowed to roam around in one area and graze off the continual re-growth of especially palatable species. Overgrazing refers to the continuous re-bite of re-growth. Approximately 60% of South Africa's soil is classified as having less than 0.5% soil organic matter (Du Preez et al. 2011). Frequent burning of rangelands reduces soil organic matter even further. WWF (2010a) stated that most of South Africa’s grazing land is already stocked beyond its long-term carrying capacity, and it is most evident in the communal rangelands of Limpopo, KwaZulu-Natal and the Eastern Cape.

Sustainability regarding beef or cattle production includes the same elements as the other systems: striving to have a lower carbon footprint, reducing GHGs, increasing water-use efficiency, improving the soil and grazing, integrating pest management, and improving the profitability in the sector. Cattle production is done in the higher rainfall areas of the semi-arid regions of South Africa. This is often combined with crop production in mixed farming enterprise systems. Beef farming or cattle production also has its own set of issues related specifically to cattle, such as water-use efficiency under beef production systems (i.e. feedlots have high water-use levels), manure and N cycles, livestock's contribution to GHGs, and animal welfare and health (see OFA 2012). Low profits from domestic stock have led to an increase in game farming (Palmer and Ainslie, 2004).

There were a number of certified cattle farmers in 2002–2004 but due to various difficulties, certified organic beef production is no longer a feature of the South African organic industry. The declining quality of good agricultural land to sustain grazing and animal production, the availability of water, perceived health concerns in beef consumption and concerns about animal health and wellbeing are all seen as major threats to the beef industry (Labuschagne et al. 2011). Demonstration and larger-scale application of more sustainable cattle production practices are much needed.
4 Conceptualising sustainable agricultural systems

4.1 Introduction

Section 3 reviewed the progress made towards sustainable farming systems in South Africa with an emphasis on production. This section broadens the scope to the whole Sustainable Agricultural Food System (SAFS), reviewing food consumption and distribution across the value chains, the quality of the system in relation to resource use, environmental impact, employment and human dignity, and the issue of food security and nutrition. The focus of this section moves beyond a discussion and measurement of individual components only to a qualitative discussion on the interrelationships between the components of a Sustainable Agricultural Food System (SAFS). The purpose of this discussion is to describe interrelationships between components to assist with the development of a system dynamics model for the South African agricultural food system, which will in turn support decision-making towards more sustainable agriculture.

4.2 Food system

4.2.1 Value chains

South Africa’s agricultural sector has shown significant structural changes in the last few decades. The number of commercial farms have declined while farm sizes have grown. Output from commercial agriculture has continued to grow based on increased efficiencies of production and a shift towards higher-value commodities, particularly in the horticultural sector and growing exports. The agriculture sector’s share of GDP has been steadily declining as the economy diversified and other sectors grew more rapidly, from 9% in 1965 to around 2% in 2012. However, agriculture has contributed significantly to secondary growth generation. Agriculture has some of the strongest backward, forward and employment multipliers in the economy, and the agro-industrial sector contributes about 12% of GDP (DAFF/IGDP 2012). The sector as a whole is a net earner of foreign exchange. However, South Africa is a net importer of processed foods and there remain good opportunities to develop local agri-food enterprises.

A typical agri-food value chain has all or some of the following components:

1. Farmers (production), input suppliers, research & development
2. Import (non-SA input suppliers, machinery, food, etc.)
3. Storage and cooling
4. Transport
5. Wholesale retail (fresh produce markets, distribution centres)
6. Formal retail (supermarkets)
7. Informal markets and outlets
8. Processing
Since this review focuses on dryland maize, beef cattle and citrus, we present a comparative overview of the value chains of these three commodities. In each case, the emphasis is on market structure and the market value chain. Each is concluded with a discussion of sustainability considerations in the value chain.

**Maize value chain**

Maize is the most important grain crop in South Africa (DAFF 2012e). More than two-thirds of the maize produced in South Africa is consumed by the local market. Of this, human consumption (white maize) accounts for 50%, the animal feed industry (yellow maize) accounts for 40% and the remaining 10% is used for seed and industrial uses such as the manufacture of paper, paint, textiles, medicine and food. South Africa meets its annual maize consumption requirements entirely from domestic production. Maize exports fluctuate from year to year depending on production levels and producer prices on local and international markets. The primary export markets are Africa, the Americas and Asia. South Africa also imports some maize mainly from the Americas, Asia, Europe and Africa, but this fluctuates significantly inter-annually.

The maize market value chain is illustrated in Figure 5.
The primary sector consists of input suppliers, producers (farmers) and silo owners. Input suppliers include companies that produce and market seed, fertiliser, products for pest, disease and weed management, irrigation equipment and farm machinery. Monsanto is currently the largest seed company in South Africa, followed by Pannar and Pioneer Hybrid International. Silo owners store maize for their own account and on behalf of others and supply it to buyers on a continuous basis throughout the year. The commercial silos, owned by 17 silo owners, account for 94% of the available silo capacity. The three major commercial silo owners, namely AFGRI, NWK and SENWES Group, own 73% of the available storage capacity within the national grain storage market.

The secondary sector consists of millers and animal feed manufacturers. Millers convert maize to maize meal for human consumption. The maize kernel is processed by two industries namely the
Wet Milling (starch extraction) and Dry Milling (maize meal) industries. Since deregulation in the mid 1990’s, the number of informal millers increased sharply from 111 to 296. The major companies include Pioneer Food Group (Pty) Ltd, Premier Foods Ltd, Pride Milling Company (Pty) Ltd, Ruto Mills (Pty) Ltd and Tiger Brands Ltd, as well as some silo owners such as NTK.

Animal feed manufacturers use yellow maize (most of the production) for the manufacture of broiler and layer feed rations. Hominy chop (a white maize by-product) is used in feedlots. The local market is fully supplied and some feed is exported to neighbouring countries. Apart from the formal (organised) feed industry, which produces 60% of all feeds, there are informal feedlots, smaller feed mills and home mixers. Business forms within the animal feeds industry consists largely of private companies, co-operatives and converted co-operatives. The major animal feed manufacturers are AFGRI, Bokomo Voere, Epol, KK Animal Nutrition, Meadow Feeds, Noordwes Voere and Senwesko Voere.

The tertiary sector consists of traders, retailers and transporters. Traders move the produce to the domestic or export market in a free trade environment. Traders include local grain traders, international grain houses and financial institutions that provide credit facilities. The large traders include Rand Merchant Bank, Senwes, Afric, Cargill, Louis Dreyfus and Verus Farms. The retail sector provides infrastructure and services for the distribution of maize products from the miller to the final consumer. The formal retail market is relatively concentrated around seven major national chain stores: Pick ’n Pay, Shoprite, Metcash, Spar, Massmart, Fruit & Veg City and Woolworths.

Transport serves to move the maize from the farmers to the silo owner, from the silo owner to the miller and from the intermediaries to the final consumers. Historically, rail transport dominated the maize market (80%). Since the early 1990s, deregulation and the development of a free market system led to a shift from rail to road transport (50:50). The rail transport industry comprises a monopoly, Spoornet. Players in the road transport sector include companies such as Unitrans, Imperial Logistics and Bidfreight.

Maize is also used to manufacture a variety of products and by-products (Figure 6).
The following are considerations to achieve sustainability in the maize value chain:

- The intensity of resource use, especially water and energy (see Figure 7), in production, milling and transport.

- The management of waste.

- The use of chemicals, especially pesticides and fungicides, in various parts of the value chain.

- Reducing carbon footprints (see Figure 7) – especially linked to on-farm fuel, electricity and fertiliser use.

- The level of real free market opportunities as opposed to high concentration and monopolies in parts of the secondary and tertiary value chain – vertical integration in this industry has led to dominant silo owners such as NWK, AFGRI and Senwes also being suppliers of production inputs, owners of trading companies, and animal feed manufacturers.
The potential impact of the emerging biofuels industry (should maize eventually be allowed as a feedstock).

Uncertainty around the safety of genetically modified (GM) maize and an inability on the part of the consumer to ascertain which products contain GM maize to make a personal informed choice.

Opportunities within the value chain for sustainably produced maize to be processed, marketed and promoted in a differentiated manner. Given the current value chain structure this is very difficult to achieve at scales larger than very small private enterprises which cannot compete with the big players. For example, organically grown maize can be certified as non-GMO and marketed directly to the market or to processors such as baby food manufacturers.

The role of energy as an input into the maize value chain has been studied recently (Mason-Jones et al. 2014). During the production stage, energy is required for soil tillage, crop management and harvesting operations, pumping irrigation water (approximately 16–20% of South African maize is currently irrigated) and fertiliser inputs (particularly nitrogen fertiliser manufactured from ammonia). Post-production, energy is required for transport from farm to silo or mill, milling, packaging and transport to retail outlets.

Figure 7 shows the contribution of each value chain stage to the overall energy required for production, transport and retail of a kilogram of maize meal. Most of the energy used (and thus the carbon footprint) is linked to the production of fertiliser and on-farm practices. A subsequent analysis showed that less than half of the retail price is paid to the farmer even though the bulk of energy has been used in this component of the value chain. This provides added justification for a drive to reduce the high level of fertiliser use for maize farming.

Figure 7  Life-cycle energy use and contribution to retail price in the maize value chain

Source: Mason-Jones et al. (2014)
**Beef value chain**

South Africa does not produce enough beef for the domestic market (DAFF 2012f) needs small letter). Therefore, imports are required annually to fill the shortfall. Imports have fluctuated in recent years between 5 and 20 million kg of beef, and originate mainly from South America and Oceania (Australia and New Zealand), as well as Ireland and India. Exports are less than 4 million kg and Africa is the main market, with Mozambique taking 73% of exports.

The South African beef industry is characterised by a duality between a highly-developed commercial sector and an informal sector with high numbers of subsistence farmers and a growing section of emergent farmers. This is an important consideration when assessing the beef market value chain (Labuschagne et al. 2011).

**Figure 8 The South African beef value chain**

The main components of the beef value chain include feed manufacturers and distributors, commercial and emerging producers, feedlots, auctioneers, abattoirs, butchers, other meat processors, exporters, importers, wholesalers, formal retail and informal retail. The beef supply chain has become increasingly vertically integrated, with the major market players (especially feedlots) owning not just their own feedlots, but also abattoirs, processors and distributors. Some feedlots have integrated further down the value chain and sell directly to consumers through their own retail outlets. Some abattoirs have also started to integrate vertically towards the wholesale level.

*Source: DAFF (2012f)*
The previous dominant role of the auction system, where wholesalers bought carcasses, has diminished since deregulation. Wholesalers are now increasingly purchasing live slaughter animals directly from farmers or feedlots on a bid-and-offer basis (i.e. they take ownership of the animal before the animal is slaughtered). The animal is then slaughtered at an abattoir of the wholesaler’s choice and the carcass is then distributed to retailers (DAFF 2012f). In some instances, the public can also buy carcasses directly from wholesalers.

With the tremendous growth in the beef industry over recent years, fuelled by the rising demand from a more affluent – mainly black – middle class, there has also been an increase in the number and capacity of abattoirs. Abattoirs are part of either the formal system (feedlots, wholesale, municipal) or they are owned by farmers and small businesses (informal). Although beef is marketed mainly fresh, chilled or frozen, it is also used in the manufacture of processed foods.

The following are considerations to achieve sustainability in the beef value chain:

- The intensity of resource use, especially water and energy, in the manufacture of feed, livestock rearing, and in abattoirs and other forms of processing.
- The management of waste.
- The use of chemicals in livestock production (for health management) and processing.
- Reducing carbon footprints – mainly linked to feed production (see Figure 9); however, imported meat would have a higher footprint owing to the carbon emissions associated with long-distance shipping of chilled/frozen product.
- The level of real free market opportunities as opposed to high concentration and monopolies in parts of the secondary and tertiary value chain (high degree of vertical integration).
- The use of GM-containing feeds in livestock rearing and an inability on the part of the consumer to ascertain which products contain GM maize to make a personal informed choice.
- Opportunities within the value chain for sustainably produced beef to be processed, marketed and promoted in a differentiated manner; for example, organic beef has not been able to gain market entry.

With respect to energy use in the beef value chain, the relevant processing stages include slaughtering, cleaning and packaging. A continuous cold chain operates between the processing facility and the retail outlet, including refrigerated display.

Energy is required primarily for the production of feed, as inferred from maize farm inputs (although there are other feed components). Another large energy user is in-store refrigeration. It could be expected that frozen meat would require significantly more energy on the processing, storage, transport and retail side.

Again, this example adds argument to the need for more sustainable lower-input production of maize and other feed ingredients.
**Citrus value chain**

The main components of the citrus value chain are the producers, packers, processors, exporters, global retail chains and consumers, and local wholesalers, retail chains and consumers (Figure 10). The industry is also linked to input supply businesses (not indicated in Figure 10) that provide nursery trees, fertilisers, chemicals, orchard care services, packaging materials and transportation (road and rail).

Although there are a minority of emerging citrus farmers and those who have benefitted from the land reform programme, they operate within the same overall citrus value chain and are served by the same input and service suppliers and the Citrus Growers' Association of Southern Africa (CGA).

![Diagram of the South African citrus market value chain](image)

**Figure 10** The South African citrus market value chain

*Source: DAFF (2012b)*

Citrus production in South Africa is mainly aimed at the export market (DAFF 2012b), with 70% of production being exported. Oranges are the leading export crop; between 65 and 70% of all oranges produced are exported, mainly to Europe and Asia (especially the Middle East), and this represents approximately 66% of all citrus products exported from South Africa. In 2011, oranges
totalling 984 116 tons and worth R4.5 billion were exported. In order of economic importance, oranges are followed by grapefruit, lemons/limes and soft citrus.

By far the majority of citrus exports make use of sea freight. At the port, citrus pallets are pre-cooled and the product is held in cold storage until it is loaded on board ship. Currently, the main port for citrus exports is Durban, which handled 675 981 pallets in 2011 (51% of total citrus exports), followed by Port Elizabeth and Cape Town (18% each), Ngqura (Coega) (9%) and Maputo in Mozambique (4%) (CGA 2012).

Locally, citrus fruit sold for the fresh market is taken to pack houses where it is graded and packed. It is then transported for distribution to the National Fresh Produce Markets (NFPs), directly to retailers, informal markets (street hawkers and bakkie traders), as well as direct sales to processors for juice making and dried fruit production. In total, 22% of citrus production is marketed locally, and around 15% of orange production. Culled fruit which did not meet the grade for the fresh market, is transported to processing plants for juice extraction. Some of the processing plants are associated with large cooperatively-owned packhouses.

The processing sector is the third most important market for South African citrus (8% of the production). The volumes of citrus available for processing in South Africa fluctuate yearly, depending on the crop size and the percentages of exportable fruit. The processing industries absorb approximately 20–25% of all citrus production. The primary product is juice (Dixie 1999): bulk juice is moved to concentrate plants for evaporation and freezing into frozen concentrate or to canning plants for retail packaging. Other processed products include candied fruit, zest, pectin, oils, marmalade, products for use in cooking, baking and making of desserts, canned citrus, dried citrus, products to mix with alcohol and pest repellents.

The following are considerations to achieve sustainability in the citrus value chain:

- The intensity of resource use, especially water and energy in production, packaging and processing.
- The management of waste.
- The use of agro-chemicals in citrus production, packaging and processing and the need to meet the local and international requirements for allowable residue levels.
- Reducing carbon footprints – mainly linked to on-farm use of electricity for irrigation pumping, synthetic nitrogen fertilisers, and diesel; the use of virgin packaging material, electricity for cooling, and the transport component, especially for exported fruit (CCC 2014).
- The increasing degree of vertical integration especially by the dominant local and foreign retailers which can lead to monopolies and barriers to entry.
- Maintenance and investment in supporting infrastructure such as roads, port handling facilities and electricity supply.
- The high administrative burden and cost of certification of sustainably produced citrus (i.e. organic citrus).

Challenges of sustainability have featured for some time in research and industry-led initiatives, driven to a large extent by international trade regulations and retailer requirements, which in turn are strongly linked to consumer demands in export destinations. The Citrus Growers Association of Southern Africa (CGA) is actively engaging with:
Meeting the requirements for Pesticide Maximum Residue Levels (MRLs)

The Confronting Climate Change (CCC) project, since its inception in 2009. This project has developed an online tool to measure the carbon footprint of the fruit (including citrus) and wine value chains and suggesting options for reducing the footprint.

The Sustainability Initiative South Africa (SIZA) which is focused on promoting sound ethical trading including labour practices on South African fruit farms and in packhouses.

4.2.2 The role of emerging and smallholder farmers in more sustainable value chains

A specific issue that deserves further attention is to link emerging and smallholder farmers to agri-food supply chains for CA, OCA and organic production systems. The focus is on the issue of access by farmers to input and output markets, and the specific needs relating to the greater adoption of CA/OCA and organic production systems. We also focus on emerging and smallholder farmers, since the input and output markets for CA and organic production systems for commercial farmers is already established and accessible to most. Such markets and production systems include availability of specialised machinery and tools appropriate for larger-scale farming, organic fertilisers and mulches, manageable transaction costs, certification schemes, and contracting models with agribusinesses, retail and export entities.

Smallholder and emerging farmers require linkages with the input and output markets in the same manner as commercial farmers; they require access to appropriate and affordable factors of production such as tools and technical support for maintenance, inputs for nutrition and pest/disease management, credit and information channels, reasonable transaction costs, and workable contracts for supplying markets (especially supermarkets and agro-processors). The government has committed itself to working towards accelerating growth in rural areas and decreasing rural poverty through the implementation of policies that include initiatives to link smallholder farmers to commercial agricultural value chains. The outcomes to date have not been encouraging owing to a multitude of barriers (Jordaan et al. 2014).

While vertical integration and its economic benefits (such as reduction in transaction costs) has become entrenched in the commercial sector, emerging and smallholder farmers rarely have the resources to achieve this even when combined into a group of small producers. This makes it difficult for smallholders and smallholder organisations to compete with larger vertically integrated agri-businesses both at the input and retail ends of the supply chain (Ortmann & King 2010). What this means for CA, OCA or organic farming systems for emerging and smallholder farmers has apparently not received much attention from researchers or policy-makers. Since such farmers are mostly non-mechanised or only have very limited access to mechanisation, non-mechanised tools for hand use or drawn by oxen which are compatible with the principles of CA or organic farming are required. These are not currently being promoted sufficiently for this farming sector in South Africa, although they are being promoted and used in similar situations in some neighbouring countries such as Lesotho, Zimbabwe and Malawi.

In a recent survey, 51 farmers who have adopted CA in the Western Cape were interviewed by the Provincial Department of Agriculture (ARC 2014) and many positive results were found relating to soil health, productivity and income. However, negative impacts were also found relating to capital expenditure (equipment costs). The adoption of CA in the region was made possible by the simultaneous development of locally adapted technologies such as robust no-till...
planters and weed control methods. The success of conservation agriculture depended on the quality of extension and research services provided. If emerging and smallholder CA in the province and elsewhere in South Africa are to succeed so that CA can be scaled up across the country, technologies for CA suited to their particular conditions and budgets (e.g. non-mechanised or ox-drawn planting equipment) will have to find greater support from research, extension and input suppliers, as well as some policy adjustments. Du Toit and Mashao (2010) stated that semi-commercial maize farmers identify a lack of access to CA-specific equipment as a challenge to implementing CA. It should be possible to assist farmers with converting their existing implements such as planters to minimum-till or no-till planters. A significant shift towards CA will necessitate the more tangible involvement of agribusiness, especially in developing cost-effective equipment.

4.2.3 Income distribution and price transmission throughout value chains

Alemu and Ogundeji (2010) studied the asymmetric price transmission between producer and retail markets in South Africa. They found that retailers respond more quickly to shocks that stretch their market margins than to those that squeeze it. They attributed this to the anti-competitive nature of the food market chain. In this situation, the free market fails to do its job and it is usually the producers who get the short-end of the stick, with only those in the middle of the value chain benefitting. In a thorough examination of this problem, Funke (2006) found that parts of the maize supply chain (milldoor to retailer), the beef supply chain, the sugar supply chain and the dairy supply chain all suffer from asymmetric price transmissions (or a lack of accurate data). The chicken supply chain and the maize supply chain (farm gate to miller) did not show these characteristics. The question then is whether the range of economic benefits from sustainable agricultural production systems will accrue equitably to all participants in the market chain.

South African producers already deal with a significant cost-price squeeze caused by a disproportionate increase in the costs of production as compared with producer prices. High proportions of farming budgets based on conventional production systems are allocated to expensive chemical inputs and on-farm fuel needs. Research on CA in the Western Cape (ARC 2014) has shown clearly the financial benefits to producers of changing from conventional to CA production systems in certain cases. Thus, this approach has the potential to rectify to some extent the unequal distribution of income which characterises the agricultural sector and could be of real benefit to raising the incomes of all farmers, but particularly of emerging and smallholder farmers. However, more research is required across different value chains before final conclusions can be made.

4.2.4 Alternative value chains for sustainably produced food

By and large, the mainstream commercial agri-food value chains are not well positioned to serve the needs of sustainable agricultural production systems. A proposed strategy for the development of an alternative value chain in South Africa for organic produce was presented by INR (2008). Considerations include the role of biotechnology in crop health and nutrition for organic systems, waste management, the regulatory and trade environment, supply and demand
in the local and export markets, costs and benefits, and socioeconomic aspects of organic agriculture.

Long value chains dilute the income and are more likely to lead to inequalities in income distribution along the chain, whereas shorter and simpler value chains are more likely to transmit price premiums to the producers.

Since retail supermarket chains in South Africa do not provide easy entry for organic produce owing to difficult demands for volumes and consistent quality (INR 2008), alternative outlets such as farmers’ markets and other direct marketing avenues provide good alternatives. The processing industry is able to absorb organic produce, for example for the processing of herbs and spices, baby food, juices, yoghurt, and canned fruit and vegetables. In all cases, however, price premiums are not guaranteed.

This has led to the situation where most of the organic produce grown in South Africa is exported. The well-developed channels and infrastructure for agricultural exports and a healthy demand in the EU, USA and Japan, in particular, make this a viable and lucrative option (Barrow 2006). Processed organic food is in increasing demand in key export markets. For example, in Germany, 75% of baby foods on supermarket shelves are organic, and similar figures are recorded in the UK.

Demand for organic produce is driven primarily by the perceived health benefits to adults and children, and secondarily by concern for the environment and the welfare of animals, on the basis of an emerging body of evidence over a few decades of practice. Equally, the development of alternative value chains for other/related forms of sustainable agriculture, such as CA, will require a sound knowledge basis of measurable and verifiable benefits to the health of humans (the consumers – if relevant), benefits to farm labour, benefits to the environment, and long-term economic benefits, in order to differentiate itself from conventional agriculture. Ultimately, CA/OCA must gain acceptance across the value chain and be demanded by informed South African value chain actors and consumers if it is to succeed and scale up to become the dominant paradigm.

4.3 Quality of the food system

The sustainability of an agricultural and food system is defined not only by the sustainability of production and consumption and the equitable distribution of value across value chains, but also by the quality of the food delivered, the demands of the system on natural resources, the loading of pollution and waste back into the environment, aspects of food security, as well as the safeguards and direction provided by laws and policies.

4.3.1 Quality of food

Quality of food can be assessed variously as the overall quality of the diet (nutrition), the safety of the food consumed (in terms of risk to cause illness or even death), and the quality of a specific food type grown under different production systems. These aspects will be discussed in the following sections.
First, South Africans have already shown interesting changes in food consumption since the 1970s. Thanks to increased wealth and post-apartheid reforms, the country’s middle class has increased by 30% between 2001 and 2004. This has allowed a shift from staple grain crops to a more diverse, although not necessarily healthier diet. South Africans have shown a decrease in the consumption of the staples maize and bread, and have massively increased their annual consumption of chicken from 6kg/pp/pa in the mid-1990s to 38kg/pp/pa in 2012/2013. Per capita egg consumption has also doubled. Interestingly, the per capita consumption of fruit and vegetables has remained constant, while beef, mutton, pork and milk consumption has initially declined, but recovered since then. The consumption of beef increased by 47% from 12.3kg/pp/pa in 2000/2001 to 18.1kg/pp/pa in 2006/2007, before declining to 16.6kg/pp/pa in 2008/2009 (DAFF 2010).

De Wit and Midgley (2012) conducted an analysis of the relationship between undernourishment across SADC and various food system indicators, and found the following:

1. A generally insufficient intake of carbohydrate and protein, but proportionally too much carbohydrate.
2. Insufficient intake of essential micronutrients.
3. A strong relationship between an increase in undernourishment and a decrease in the consumption of fruits and starchy roots.

In South Africa, sufficient food, including fresh fruit and vegetables, is almost always available, but still a high number of South Africans suffer from poor nutrition. Most of the population remains highly reliant on staple grains (maize) supplemented with some vegetables. The government has introduced fortification of staple foods with essential micronutrients in order to combat certain deficiencies. The rising middle class is turning increasingly to calorie-dense but nutritionally poor convenience foods, more meat (mainly chicken), fats and sugar, but too little fruits and vegetables. The key factors which influence fruit and vegetable consumption patterns are income (or rather lack of it), high prices and seasonal availability, consumer taste preferences, education level, home production, and intra-household decision-making. Weak market integration is an important driver of high prices at the local level. Even in urban areas where food supply chains exist and fruit and vegetables are usually freely available, a high proportion of people cannot afford or choose not to buy these foods (Midgley & De Wit 2013).

Arguably the most vulnerable group is children. An analysis of a national survey conducted in 1999 (Naudé 2007) showed that children between the ages of one and nine years were consuming only 110 grams of fruit/vegetable per day, about a third (young children) to a quarter (older children) of the minimum requirement for children. Significantly, the vast majority of both rural and urban households purchased their fruit/vegetables, and only those living in Gauteng and the Western Cape provinces were able to afford reasonable provision of these food groups to their children. Children also generally do not eat enough protein which contributes to poor growth rates.

Second, food safety is a primary concern for the agro-food industry. The food sector is subject to stringent legislation and regulation aimed at ensuring that food reaching the consumer is not harmful to his/her health. Figure 11 illustrates the rigorous quality control mechanisms which exist in the fruit and vegetable supply chains in order to ensure food safety. Similar mechanisms exist for grains, meat and dairy.
Despite these measures there exist a number of risks to food safety which appear to be increasing. Britz and Sigge (2012), in an in-depth review, found that contamination in South African river water that is used for irrigation purposes shows high concentrations of faecal indicators and numerous other pathogens which can cause severe illnesses in humans. Water from some rivers studied was unsafe for irrigation of fresh produce. Measurement of irrigated fresh produce did indeed show high levels of contamination with potential pathogens and most of the samples could be classed as microbiologically unsatisfactory relative to standards set by the World Health Organisation, the South African government, and retailers. Inadequate wastewater treatment plants or poor management and maintenance of such plants for rural and urban settlements, as well as the lack of safe sanitation in many parts of the country, are largely to blame. The potential impacts on agriculture can be severe, particularly for fresh produce aimed at the export market.

In addition to microbial contamination, water quality concerns are related to the following problems often associated with intensive industrialised agriculture – the impacts become evident both in the functioning of aquatic ecosystems and in downstream agriculture (crop irrigation and livestock watering):

- Salinization of soils and run-off water due to inappropriate and unsustainable irrigation practices.
- The accumulation of pesticide and herbicide residues in the surface waters, biota and sediments downstream of intensive irrigation areas. Concerns have also been expressed about the presence of endocrine-disrupting chemicals (EDCs) in surface waters near intensive irrigation systems. Persistent organic pollutants (POPs) and EDCs are not monitored routinely in many of the country’s river systems.
High organic loads to rivers caused by intensive piggeries, dairies and feedlots. Organic compounds consume oxygen when they decompose in rivers thereby reducing the dissolved oxygen concentrations and negatively impacting aquatic organisms. Discharges not complying with chemical oxygen demand (COD) standards and irrigated effluents high in organic content that are washed into rivers have similar impacts on aquatic ecosystems.

Not only are river systems (and groundwater in some cases) negatively affected by some industrial agricultural practices, but soils themselves can also become contaminated with heavy metals and other toxins owing to long-term use of toxic agro-chemicals. These then make their way into the food system.

Third, there exist strongly divided opinions as to whether food grown under conventional versus other more sustainable types of production systems is of differing quality. For example, organically grown fresh produce has a higher proportion of “lesser” quality products as measured by external cosmetic features and blemishes, but its proponents and a growing body of researchers claim that it is nutritionally superior to conventionally grown produce.

Interestingly, South African consumers are trending towards a growing interest in “alternative quality” and healthier options, with retailers responding accordingly (Bienabe et al. 2011). Thus, free-range eggs and meat, “certified natural” or “Karoo lamb”, organic ranges, and other sustainability labels (ecological-ethical) are in demand from consumers who perceive them to have better taste, aroma and texture. However, this (still small) market is dominated by the formal retail sector, and is poorly developed among consumers in the informal market.

4.3.2 Natural resource use

According to the FAO, agriculture in South Africa uses 63% of freshwater in the country and a total of 1.67 million ha was under irrigation in 2012.

Arable land and permanent crops use 12.41 million ha (10.8%) of the country’s total agricultural area, which is approximately 79% of total land area.

Energy accounts for South Africa indicate that the agricultural sector used 70 002 TJ of energy in 2001 (0.85% of total energy use in the country), comprising the following main energy types: diesel (55%), electricity (20%), vegetable waste (10%) and coal (9%) (Statistics South Africa 2005).
4.3.3 Waste and pollution

Henao and Banaante (1999) estimated that the average annual loss of nutrients in South Africa amounted to 110 900 tons per annum between 1993 and 1995, or 14kg/ha/year. Although this is one of the lower depletion rates in Africa, they calculated that South Africa still needs in excess of 80kg/ha/year to maintain current yields without depleting nutrients. Fertiliser consumption on arable land and land under permanent crops in South Africa is currently around 60kg/ha/yr (FAOSTAT). However, not all of these nutrients are applied effectively.

A comprehensive overview by De Villiers and Thiart (2007) has shown that nutrient levels exceeded recommended water quality guidelines for plant life in all but one of South Africa’s 20 largest river catchments. Seasonal nutrient profiles are consistent with fertiliser applications in many of these rivers (De Villiers & Thiart 2007:345), signifying a significant loss of fertiliser-equivalent nutrients in the agricultural economy.

South Africa is one of the largest importers and users of pesticides in Africa, and its use has increased substantially since the mid-1990s (see Table 6). Many studies have highlighted the occurrence of pesticides in water resources (Dabrowski 2013) as well as its possible effects on food safety and public health.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Pesticide use in South Africa from 1994 to 2000</th>
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<tbody>
<tr>
<td>South Africa</td>
<td>Fungicides &amp; Bactericides + (Total)</td>
<td>1331</td>
<td>3,352.00</td>
<td>5,211.00</td>
<td>5,509.00</td>
<td>7,034.00</td>
<td>6,706.00</td>
<td>6,420.00</td>
<td>8,928.00</td>
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<tr>
<td>South Africa</td>
<td>Herbicides + (Total)</td>
<td>1320</td>
<td>7,618.00</td>
<td>7,390.00</td>
<td>7,938.00</td>
<td>9,437.00</td>
<td>9,669.00</td>
<td>10,659.00</td>
<td>9,469.00</td>
</tr>
<tr>
<td>South Africa</td>
<td>Insecticides + (Total)</td>
<td>1309</td>
<td>4,285.00</td>
<td>4,105.00</td>
<td>4,564.00</td>
<td>3,569.00</td>
<td>6,311.00</td>
<td>7,210.00</td>
<td>6,158.00</td>
</tr>
<tr>
<td>South Africa</td>
<td>Plant Growth Regulators + (Total)</td>
<td>1356</td>
<td>1,175.00</td>
<td>1,210.00</td>
<td>1,414.00</td>
<td>1,465.00</td>
<td>1,528.00</td>
<td>1,747.00</td>
<td>2,265.00</td>
</tr>
<tr>
<td>South Africa</td>
<td>Seed Treatment Fungicides + (Total)</td>
<td>1352</td>
<td>152</td>
<td>110</td>
<td>83</td>
<td>91</td>
<td>90</td>
<td>63</td>
<td>37</td>
</tr>
</tbody>
</table>

Source: FAOSTAT (2014)
The South African agricultural sector contributed a net amount of 20 494 Gg CO₂e of greenhouse gases, which is 5% of the country’s total net greenhouse gas emissions (DEA 2011). According to DEA (2011), the main driver is enteric fermentation in ruminant animals.

4.4 Food security

4.4.1 Food availability

Food availability addresses the supply-side of food security and is determined by the level of food production, stock levels and net trade, as well as distribution and exchange of food. Current thinking suggests that domestic production, reliable import capacity, presence of food stocks, availability of social protection measures, decent transportation infrastructure and, when necessary, access to food aid are the major elements of securing food supply (Ziervogel & Ericksen 2010).

South Africa is considered nationally food secure, that is at national level there is enough food available for the whole population (BFAP 2013; Hendriks 2013). Food availability is estimated at more than 3000 kcal/capita/day in 2011 (FAOSTAT 2013), up from 2 796 kcal/capita/day in 1996. This amount is more than the average daily dietary energy requirement of 2 400 kcal/capita/day established by the FAO/WHO. During this period, the per capita supply of substances providing energy (proteins and fats) has also risen. The average per capita daily protein supply rose from 78g to 84g from 2004 to 2009.

Overall production levels and food supply have kept pace with population growth and even exceeded it. The annual growth rate of per capita food production has been particularly healthy in the period 2007–2012, when it reached 2.11% (FAOSTAT 2013). Imports, exports, stock levels and net trade fluctuate from year to year, depending on national production levels, international markets (production, stocks, prices) and changing patterns of demand (DAFF 2012c). The main imports include wheat, rice, palm oil, poultry meat, soya bean and other vegetable oils, and sugar (BFAP 2013).

Figures 13 and 14 illustrate the differences between a staple grain which is produced in excess of demand (white maize) and one which is not produced nationally in volumes sufficient to meet demand (wheat) (BFAP 2013). The trend towards greater consumption of wheat, fuelled by the preferences of the growing middle class, could see the country moving towards a situation of production deficit and net import of grains.
From a sustainability perspective, some of the cheap imports are produced using practices which are less sustainable than those used by local farmers, and the produce is of lower quality. These cheap foods often contain unhealthy ingredients such as cheap varieties of oil, high levels of sodium, and multiple preservatives, additives and flavourants (Hendriks 2013). Imports are not subjected to the same high level of food safety standards and inspections as local produce, particularly that grown for the country's main export destinations such as the EU. This discourages local farmers and is perceived as unjust and anti-competitive. In essence, harmful practices ("bad footprints") are imported virtually.
Another area of concern is the interdependence among countries in their food supplies, plant genetic resources and nutritional priorities (Khourya et al. 2014). Within a global trend of increased overall quantities of food calories, and increased proportions of those quantities sourcing from energy-dense foods, national food supplies have diversified in regard to contributing measured crop commodities. As a consequence, national food supplies globally have become increasingly similar in composition, based upon a suite of truly global crop plants. The growth in reliance worldwide on these crops heightens interdependence among countries in their food supplies, plant genetic resources and nutritional priorities. Species diversity has been shown to stimulate productivity, stability, ecosystem services, and resilience in natural and in agricultural ecosystems. Likewise, variation in food species contributing to diet has been associated with nutritional adequacy and food security. South African commercial agriculture does not yet embrace the wide range of indigenous crops and livestock breeds which could be produced under sustainable farming systems and provide greater agricultural resilience to shocks and improved nutrition, despite support for research in this area.

Food is available from three primary sources: formal markets and retail, informal markets and outlets, and own production. In South Africa, the formal sector dominates the food market chain and often supplies the informal outlets, for example through the Fresh Produce Markets. In urban areas, food is purchased from supermarkets, but more frequently from small informal shops, take-aways and street vendors. Rural spaza shops usually have a very limited diversity of food on offer, which also tends to be more expensive than in the cities. Nevertheless, a very high proportion of South Africans purchase most of their food requirements from these vendors.

Own production of food for household consumption varies considerably across the country. The 2011 Population Census estimated the number of households engaged in agriculture (also referred to as agricultural households) at 2.9 million (Statistics South Africa 2011b). Nationally, 24.9%, 20.7% and 16.3% of agricultural households were located in KwaZulu-Natal, Eastern Cape and Limpopo, respectively. The lowest percentage of agricultural households were recorded for the Northern Cape and Western Cape at 1.9% and 2.9%, respectively. The most common agricultural activities include the keeping of livestock (primarily cattle and poultry) and vegetable production, with some areas (Limpopo) also practicing fruit production.

The same census (Statistics South Africa 2011b) also showed that agricultural households are generally poor: in 30% of such households nationally, the head of the household receives no income, and a further 55% have a low annual income (less than R38 400 per annum). Household food production is making a small contribution to providing for the needs of these households, but this is variable across the country and is usually limited to vegetables, poultry meat and eggs, and occasionally milk, red meat and fruit.

An important consideration in a rapidly urbanising country is the production of food in urban environments and settlements. This can make an important contribution to food security although opinions are divided as to its real impact at household level in South Africa (Hendriks 2014; Crush et al. 2010). This occurs either at commercial or semi-commercial scale on farmland within urban boundaries, for example Philippi in Cape Town (Battersby-Lennard & Haysom 2012), or at subsistence scale in backyards, open public spaces or private rented land within the cities and in the peri-urban zone. Communal food gardens have also been promoted by government, non-governmental organisations (NGOs) and community-based organisations (CBOs).
South African cities have unusually low rates of household food production at 9% in Johannesburg and only 5% in Cape Town, compared to an average of 22% in a cross-section of cities in SADC (Crush et al. 2010). When asked how often they obtain food from their own gardens or fields, only 1% of household producers in Cape Town responded that they get food from this source at least once a week and another 1% at least once a month. Corresponding figures for Johannesburg are 2% and 1%, respectively. The general pattern across SADC seems to be that it is only in cities with absolute food shortages, such as Harare, and the poorer areas of the poorest cities that food production for home consumption is a normal source of food (Crush et al. 2010).

Household production of food (vegetables) is frequently characterised by a lack of, or too little, compost since most households do not generate enough organic waste material to produce compost for their gardening needs (Richards & Taylor 2012). For this reason, food gardens attached to public institutions such as schools and clinics have had better success since they generate sufficient organic waste. Similarly, pest and disease control are often poor, since agrochemicals are not generally used. Both production levels and quality of the produce would benefit from sustainable and affordable production technologies at this scale.

Taking a longer-term view, the current ability of South Africa’s farmers to continue meeting the increasing demand for food is expected to be tested by the emerging impacts of climate variability and climate change on production (DEA 2013; Ziervogel & Ericksen 2010). Climate change will reduce the productivity of a number of staple and high-value crops, disrupt the supply chain and lead to an increasing need to import food from elsewhere. Many agriculture-dependent livelihoods and vulnerable food-insecure people could be exposed to increased risk unless production systems are adapted to the new conditions (HLPE 2012). CA, for example, has proven benefits as a climate change adaptation strategy, while at the same time contributing to mitigating and reducing harmful greenhouse gas emissions.

4.4.2 Access to food

Although it is a multi-dimensional phenomenon, which is often difficult to define and understand, food security in South Africa is largely about direct or indirect access to cash to purchase food (Chopra et al. 2009). Since 2000, South Africa has experienced two serious food price crises, namely in 2002 and 2007. The high prices of 2007 settled back to lower levels for a period after which there was an unprecedented upward trend in food prices generally. Owing to “purchasing power” being the key determinant to food security, the poor have suffered the most from these increases. In a country where access to food is largely predicated by food prices, the political reaction and response to this situation reveals a great deal about how government understands and responds to food insecurity (Kirsten 2012). As shown in Figure 15, South African basic food prices increased steadily across a broad spectrum of a food basket. This is particularly important when looking at the urban context, where food purchases is the dominant means of accessing food.
Figure 15  Basic food prices in South Africa, November 2000 to November 2012

Source: Holloway et al (2013)

4.4.3 Utilisation of food

The following section draws on the review conducted by Schönfeldt on the nutrition impact of food systems on behalf of the United Nations Standing Committee on Nutrition (2003). In addition, a wide range of other literature is pulled together to demonstrate the adverse health and nutrition outcomes of the South African food system, which is the intention of this section.

South Africa is a middle-income country with an estimated population of nearly 53 million (Statistics South Africa 2013). Nearly two-thirds (62%) of the population resides in urban areas, with the number consistently increasing due to urbanisation. Many people living in rural or peri-urban areas commute daily or weekly to urban centres, whether metropolitan areas or larger towns in the rural hinterland, for work. This strengthens a strong link between rural areas and many of the urban/industrial areas (Kirsten 2012).

The country is experiencing a nutrition transition in which under-nutrition, notably stunting and micronutrient deficiencies, co-exist with a rising incidence of overweight and obesity and the associated consequences such as hypertension, cardiovascular disease and diabetes (Schönfeldt 2013). Within the context of the AIDS pandemic and food insecurity, the high prevalence of under-nutrition, micronutrient deficiencies and emergent over-nutrition presents a complex series of challenges.

Under-nutrition has stayed constant in South Africa since the early 1990s. Despite the relatively high per capita income, rates of childhood stunting (18% of children under 6 years (NFCS-FB-I 2008)) are comparable to low-income countries in the region and higher than in lower-income countries in other regions. While some indicators show improvement, several conditions seem to have worsened over the past decade (NFCS-FB-I 2008).

During the period 1985 to 1994, Statistics SA estimated life expectancy at about 54.12 years for males and 64.38 years for females. This has improved for males to an estimated 57.7 years but decreased for females to 61.4 years (Statistics South Africa 2013). South Africa is also one of only 12 countries in the world in which mortality rates for children younger than 5 years increased
between 1990 and 2008 (Black et al. 2008) although there has been an improvement in the push towards achieving the Millennium Development Goals.

The high incidence of stunting observed in children indicates a chronic or severe deficiency in essential nutrients/micronutrients during the growing years and it is a significant concern in South Africa. In 1994 stunting in children (6 to 71 months) was recorded as 22.9% (SAVACG 1996). In 1999 stunting was recorded as 21.6% (NFCS 1999) and by 2005, after the implementation of the mandatory fortification of staple foods, 18% of children were still recorded as being stunted (NFCS-FB-I 2008). Stunting is a risk factor for increased mortality, poor cognitive and motor development and other impairments in function. It usually persists into adulthood, resulting in smaller size and diminished work function (Iverson et al. 2011).

In contrast, 25% of adolescents and 56% of the adult population were recorded as overweight or obese (Reddy et al. 2010; DoH 2003) indicating excessive intake of energy. Furthermore, nearly 30% of all deaths were attributed to non-communicable diseases (NCDs) (WHO 2011) with cardiovascular disease (11%) and cancers (7%) being the largest contributors (WHO 2011).

In 2000, the Medical Research Council (MRC) performed a comparative risk assessment for South Africa, and found that eleven of the seventeen most common risk factors for deaths were directly or indirectly related to nutrition, and included among others high blood pressure, excess body weight, high cholesterol, diabetes, low fruit and vegetable intake, vitamin A deficiency and iron deficiency/anaemia (Norman et al. 2007).

In terms of nutritional deficiencies, in 1994 it was found that 33% of children under 6 years were marginally deficient in vitamin A (serum retinol <20mgdL-1), with the highest rates recorded among children aged 3 to 4 years. In 1999 it was recorded that one out of two children under the age of 9 years consumed less than half of the recommended levels of energy, vitamin A, vitamin C, riboflavin, niacin, vitamin B6, folate, iron, zinc and calcium. In this national study, diets of children were confined to a narrow range of foods of low micronutrient density.

Dietary intakes were particularly inadequate in rural areas (Labadarios et al. 2011). After the mandatory fortification of staple food with a fortification mix (vitamin A, B-vitamins, zinc and iron) was legislated in October 2003, a follow-up national survey in 2005 still found significant nutritional deficiencies in children and women. Nearly 30% of children and women had anaemia, 64% of children and 28% of women had a vitamin A deficiency and 45.3% of children had a zinc deficiency (NFCS-FB-I 2008). Children's nutritional status varies considerably among the nine provinces and possibly within each province.

The costs of malnutrition are often not factored into the development “calculations” facing the country and, as such, the limits on human and economic potential are not politically prioritised. Severe malnutrition early in life, including in utero and during the first two years, leads to stunting – the physical and mental underdevelopment of children. Mentally, this means changes to brain cell development and a reduction in the “connectivity” or “branching” between brain cells. Brain underdevelopment has an obvious and serious impact on mental ability. Children subjected to severe malnutrition in the first two years of their lives may be at a permanent intellectual disadvantage. Even with interventions later in life, they are unable to “catch up” on the missed brain development stage. They have difficulties learning and later, participating in the economy.

Malnutrition also leads to increased morbidity and mortality; people who are malnourished, or were malnourished in early life, tend to get sick more often and are more likely to die when they
get ill. These effects of malnutrition perpetuate poverty and retard both personal and national economic development. Inaction over malnutrition, in terms of educational, health and economic outcomes, costs the individuals involved and the country more than is often realised.

4.4.4 Stability

The South African National Health and Nutrition Examination Survey (SANHANES-1) aimed to provide a comprehensive snapshot of food security in South Africa and reveal something about the stability of the system to provide access to safe and nutritious food at both national and household levels. A few key statistics from the survey indicate that overall 45.6% of the population was food secure; the largest percentage of participants who experienced hunger (food insecurity) were in urban informal (32.4%) and in rural formal (37.0%) localities; by province, the prevalence of hunger was the lowest in the Western Cape (16.4%) and Gauteng (19.2%) with the Eastern Cape and Limpopo being the only two provinces with a hunger prevalence higher than 30.0%; demographically, the black African race group had the highest prevalence of food insecurity (30.3%), followed by the coloured population (13.1%) and a large percentage (28.5%) of the Indian population was also at risk of hunger whereas the majority (89.3%) of the white population was food secure, which was significantly higher than all the other race groups (Shisana et al. 2013).

In terms of trends, data from 2002–2007 shows a general decrease in the experiences of hunger by households (Labadarios et al. 2011; Aliber 2009), but rates of stunting, micronutrient deficiencies, and hunger and food insecurity continue to be unacceptably high, as argued in the previous section. One explanation of this is an increasing reliance on food purchases, which increase vulnerability to food security by discouraging home production and at the same time making households more vulnerable to economic shocks causing food price increases (Hendriks 2005). A growing number of studies have emphasised this growing dependence on market purchases for procuring food in South Africa (Baipheti & Jacobs 2009). This trend has been seen as a function of supermarkets being able to offer relatively cheaper food, even in rural areas where they are outcompeting local stores (Caesar & Crush 2014; D’Haese & Huylenbroeck 2005). The social grant system has been identified as providing a strong incentive to purchase food, maintaining a reliance on local stores and supermarkets rather than on food production in rural areas and thereby undermining the ability of households to invest in household food production (Pereira et al. 2013; Thornton 2008).

This raises the importance of looking at food security in metropolitan areas and other urban centres – the urban food system – that has been highlighted in recent publications (Battersby 2012; Battersby 2011a; 2011b). Battersby and Peyton (2014) map the location of supermarkets in Cape Town illustrating the highly unequal structure of the urban food system that limits the urban poor from accessing healthy foods. In contrast to this, there has been increasing attention on urban food production and community food garden projects. Some studies emphasise the importance of urban farming for contributing to household income and food security (Thornton 2008). However, Crush et al. (2011) ascertained that in general food production is not significant among urban populations, although this differs between cities, but that many more households rely on supermarkets and the informal sector to access food.
5 Comparing conventional and sustainable agriculture and food systems

In the previous sections an overview was given of the main aspects that characterise the South African farming, food and nutrition system. The question unaddressed so far is whether the great balancing act of feeding more people in a more sustainable way can in fact be achieved through alternative farming systems. The next step is to provide a brief overview of the main results worldwide and specifically for South(ern) Africa on comparisons between conventional and alternative agricultural and food systems.

5.1 General results worldwide

The review presented here is restricted to studies that present meta-analyses of comparative studies. The first general observation is that increased economic benefits are not directly associated with organic farming, conservation agriculture, or NT technologies. The results are nuanced and require case-specific analysis. Uematsu and Mishra (2012) pointed out that in the US certified organic farmers do not earn significantly higher household income than conventional farmers as higher revenues are generally offset by higher input costs. Pannella et al. (2013) reviewed the limited high-quality literature on farm-level economics of conservation agriculture and pointed out that the economics of CA will have to be considered on a case-by-case basis. They identify several key factors discouraging adoption of CA, namely ”...the opportunity cost of crop residues for feed rather than mulch, the short-term reduction in yields under zero tillage plus mulching in some cases, combined with short planning horizons and/or high discount rates of farmers, farmer aversion to uncertainty, and constraints on the availability of land, labour and capital at key times of year” (Pannell et al. 2013). There is a clear need for high quality and context-specific economic analysis when comparing conventional and alternative agricultural systems.

The second observation is that yields are typically lower for organic farming systems, but much variation occurs. Based on a dataset of 362 organic-conventional comparative crop yields, De Ponti et al. (2012) concluded that ”...organic yields of individual crops are on average 80% of conventional yields, but variation is substantial”, with the yield gap differing substantially between crop groups and regions. Seufert et al. (2013), using a dataset of 316 organic-conventional yield comparisons across 34 crop species, points out that yield differences are ”...highly contextual, depending on system and site characteristics”, but under certain conditions (e.g. good management practices, crop types, growing conditions) organic systems can almost match the yields in conventional systems.

The third observation is that positive impacts of alternative farming systems on environmental indicators are most notable for soil organic matter (SOM) and biodiversity indicators (Tuck et al. 2014; Tuamisto et al. 2012; Mondelaers et al. 2009). Bengtsson et al. (2005), in a meta-analysis of 66 publications comparing organic and conventional farming systems, concluded that ”...organic farming often has positive effects on species richness and abundance, but that its effects are likely to differ between organism groups and landscapes”. Bengtsson et al. (2005) argued that positive effects on species richness are expected in intensive agricultural landscapes.
and not in small-scale landscapes within other biotopes, a finding mirrored by Tuck et al. (2014) based on an updated analysis of 94 studies. Tuck et al. (2014) further pointed out that positive effects on biodiversity also varies across organism group and crops. Gabriel et al. (2013), however, pointed out that such biodiversity gains in highly productive agricultural systems would come at the expense of a reduction in yield and argue rather for a direction of conservation efforts to lower-productive or non-agricultural land.

The fourth observation is that apart from SOM and biodiversity gains, the only environmental impacts that differ significantly between organic and conventional farming systems (in Europe) are nitrogen leaching, nitrous oxide emissions per unit of field area, energy use and land use (Tuamisto et al. 2012). According to these authors, organic farming has lower energy and higher land use requirements, higher eutrophication and acidification potential, as well as higher nitrogen leaching, higher nitrous oxide emissions and higher ammonia emissions per product unit. Tuamisto et al. (2012) also pointed out that organic farming generally does have positive environmental impacts per unit area, but due to lower yields and requirements to build fertility of the soils, not per product unit. This finding is largely consistent with an earlier study by Mondelaers et al. (2009), apart from the results on nitrogen leaching which Mondelaers et al. concluded to be slightly lower per product unit for organic farming systems. This diverging result can possibly be explained by the inclusion of non-European studies (Tuamisto et al. 2012:316), but the debate on nutrient leaching by organic farming systems is far from settled. Tonnito (2006) performed a meta-analysis on experiments comparing crop yield and nitrate leaching between conventional and diversified systems and found that "...nitrate leaching was reduced by 40% in legume-based systems relative to conventional fertilizer-based systems". Tuamisto et al. (2012) concluded that the "...key challenges in conventional farming are to improve soil quality (by versatile crop rotations and additions of organic material), recycle nutrients and enhance and protect biodiversity. In organic farming, the main challenges are to improve nutrient management and to increase yields". The debate now moves beyond conventional versus organic systems to the design of ‘optimal’ integrated farming systems focused on combining technologies (Tuamisto et al. 2012:318).

The fifth general observation relates to the effect of alternative farming systems on greenhouse gas emissions. Venkat (2012) reported on a cradle-to-farm gate life cycle assessment performed on 12 crop products grown in California and concluded that organic production may offer "...significant GHG reduction opportunities" by increasing the soil organic carbon stocks. It must be noted that significant variations in the results do occur with the type of organic system employed. Similar results were reported in modeling study by Kustermann et al. (2008). The trade-off between a reduction in greenhouse gas emissions on more extensive production methods and the amount of beef life-weight that can be produced per hectare was pointed out by Casey and Holden (2006) in a study on Irish suckler-beef.

A sixth observation is that results of meta-analyses studies are divided on the differences in nutritional quality of organically or conventionally produced food. Dangour et al. (2009), on the basis of a systematic review of studies of satisfactory quality, concluded that there is "...no evidence of a difference in nutrient quality between organically and conventionally produced foodstuffs. The small differences in nutrient content detected are biologically plausible and mostly relate to differences in production methods". Jensen et al. (2013) also found that agricultural practice has "...no clear effect on health-related biomarkers". Lairon and Huber (2014) lamented that scientific evidence regarding the effects of organic food on health is still
lacking. Smith-Spangler et al. (2012), who confirmed only that consumption of organic foods may reduce exposure to pesticide residues and antibiotic-resistant bacteria, concluded that “...the published literature lacks strong evidence that organic foods are significantly more nutritious than conventional foods”. However, the most recent and most rigorous statistical review conducted to date on the subject (Barański et al. 2014) found that organic crops/crop-based foods, on average, have higher concentrations of antioxidants such as polyphenolics, lower concentrations of the toxic metal cadmium (Cd), and a four times lower incidence of pesticide residues than the non-organic comparators across regions and production seasons. There is evidence that higher antioxidant concentrations and lower Cd concentrations are linked to specific agronomic practices (e.g. non-use of mineral N and P fertilisers, respectively) prescribed in organic farming systems. In another recent study, Brandt et al. (2011) established that the content of secondary metabolites in fruits and vegetables was approximately 12% higher in organic produce than in corresponding conventional samples, with a larger difference for defense-related compounds and no difference for carotenoids. This corresponds with the predictions from ecology and fertiliser studies, indicating that the differences in content primarily are caused by the differences in fertility management between the systems. If secondary metabolites are responsible for the health promoting effect of consumption of fruits and vegetables, then this means that switching to organic produce will benefit health as much as a 12% increase in intake of fruits and vegetables (Brandt et al. 2011). Barański et al. (2014) argued that the upsurge in research has only now provided a critical mass of studies, which, together with more sophisticated statistical methods, is able to differentiate between organic and non-organic produce quality.

5.2 Results of comparative studies on farming systems in South(ern) Africa

It must be noted that the above analysis contains little information from Africa as very little published comparative studies are available. In this section we pay specific attention to studies that have been done in South(ern) Africa that could be beneficial in informing further analysis and modelling for the South African context, with specific reference to field crops (maize), horticulture (citrus) and livestock (beef).

5.2.1 Field crops

The benefits of applying CA to South(ern) African farming systems has been pointed out in various field-level studies. A study on the adoption of CA among 8 NT and 22 RT commercial grain farmers in the North West Province, reported reduction in production costs and a substantial increase in yield and net farm income (Du Toit 2007). In an analysis of field cropping systems in the Eastern Free State, Knot (2014) concluded that CA effectively mitigates GHG emissions through the sequestration of organic carbon in the soil. Thierfelder et al. (2012) concluded, based on a study of the effects of CA on soil parameters and maize yield over 8 cropping seasons in Malawi, that “...that maize yields in CA systems were strongly affected by rainfall infiltration, which was 24–40% greater compared with the conventional ridge and furrow system [and] in some cases, maize yields in CA plots were double that of conventional tillage plots”. Thierfelder et al. (2012) in another study based on field-level studies in Zimbabwe, concluded that maize in rotation with cowpea or sunnhemp and maize intercropped with cowpea or pigeonpea show
“...marked benefits of rotation especially in CA systems”. Similar positive results were reported in Zambia (Thierfelder et al. 2013). Rusinamhodzi et al. (2011) showed that “…an increase in maize yield over time with conservation agriculture practices that include rotation and high input use in low rainfall areas”.

Despite such apparent positive results on a farm level, the uptake of CA in sub-Saharan Africa is very slow. Giller et al. (2009) pointed out that empirical evidence is not always clear and constraints to adoption include competing uses for crop residues, increased demand for labour for weeding and lack of access to needed external inputs. Rusinamhodzi et al. (2011) also pointed out that demonstrated field level benefits will not “…increase the overall adoption of rotations and intercropping in CA systems, unless the socio-economic constraints at the farm and community level are addressed”. Corbeels et al. (2014a) highlighted that success of CA on farms has been limited so far, and rather needs to be targeted to end-users and adapted to the needs of local farmers. In another study Corbeels et al. (2014b) emphasised the importance of mulching and crop rotation for achieving increased crop yields in RT or NT systems, but pointed out that these two components of CA are for many smallholder farmers in sub-Saharan Africa the main bottlenecks to adopting CA. Crop residues can be used as feed for livestock and cover crops such as legumes or other non-cereal crops in many cases do not have ready markets available. A key challenge for CA in small-scale (Southern) African farming systems is to gather empirical information on all aspects of CA across various scales and regions and to devise strategies to mainstream and upscale the approach (FAO 2009).

5.2.2 Horticulture

In earlier years, it was reported that most of the farms converted to organic production were horticultural holdings that were smaller than the average commercial farms (Niemeyer & Lombard 2003). No empirical studies were found that measured the different outcomes of conventional and alternative horticulture production systems in South Africa. Several studies do report on natural resource and environmental indicators such as energy use, soil fertility, greenhouse gas emissions, biodiversity maintenance and pollution.

For example, a survey of occurrence of entomopathogenic fungi was undertaken on soils from citrus orchards and refugia on conventionally and organically managed farms in the Eastern Cape Province (Goble et al. 2010). There was a significantly higher occurrence of entomopathogenic fungi in soil samples taken from refugia compared to cultivated orchards, but no significant differences were observed in the recovery of fungal isolates when soil samples from both farming systems were compared. One reason could be that conventional farming practices in the Eastern Cape are considered ‘soft’ with much emphasis placed on IPM instead of intense pesticide loads. Other factors included the history of the orchard and period of conversion from conventional to organic, and the use of microbial products by some farmers in both systems.

In another example, Kehinde and Samways (2012) studied the effects of organic management of vineyards (versus conventional management) and landscape context on two highly endemic and important pollinator taxa (bees and monkey beetles) in the Cape Floristic Region (CFR) biodiversity hotspot. Species richness of monkey beetles, but not the species richness of bees, benefited from organic compared to conventional vineyard management. This suggest that the effects of landscape context and management may be taxon dependent.
5.2.3 Livestock

Not many empirical comparative studies on alternative beef production systems were found in South Africa. Esterhuizen et al. (2008) found that feedlot cattle showed a higher profit than conventional and organic pasture groups, mainly due to faster and more efficient growth. The organic pasture cattle showed higher profit than the conventional pasture cattle as a result of the premium paid for the organically-produced meat. Cattle raised in the feedlot grew faster and produced larger carcasses than cattle raised on conventional and organic pastures. A higher premium has to be negotiated, if conventional pasture or organic producers want to compete with feedlot producers (Esterhuizen et al. 2008:314).

Reference is further made to other countries before looking at South African studies conducted in this regard. Vintila (2011) conducted a research on both the ecological footprint (EF) and carbon footprint (CF) of organic and conventional agro-production and processing. Organic beef production had lower EF and CF relative to conventional beef production (Vintila, 2011:36) (see Figure 16 below for details).

![Figure 16](image)

**Figure 16** CO₂ emissions (t CO₂ / t) and Ecological Footprint (gha/ t) for farm meats

*Source: Vintila (2011)*

5.3 Towards an acceptable framework for comparative analysis

Comparative studies between conventional and alternative systems have and can be done, but need to be sensitive to various issues, such as the following:

- First, the technologies used (e.g. OCA, NT, CA) to describe alternative sustainable agricultural systems need to be well-defined, including exact specifications on cover crops and length of crop rotations.
- Second, the results of comparative studies are sensitive to site-specific factors such as crop types, regions, growing conditions, management practices, landscapes (e.g. intensive
or smaller-scale) – such factors need to be quantified and included in the design of comparative models.

- Third, how environmental impacts are expressed matters. As yields are typically lower for organic farming systems, an important feature in the design of comparative studies is to express environmental impacts not only on per area, but also per product.

- Fourth, the type of environmental impact parameters that are compared matter as well. Indicators that have been used include soil organic matter (SOM), biodiversity indicators, nitrogen leaching, nitrous oxide emissions, ammonia emissions, eutrophication potential, acidification potential, soil organic carbon (SOC) and greenhouse gas emissions. Resource use parameters include energy-, water- and land use.

- Fifth, indicators on nutritional quality need to be included and includes parameters such as pesticide residue, antibiotic resistant bacteria, antioxidants and toxic metals.

- Sixth, there is a clear need for high-quality and context-specific economic analysis when comparing conventional and alternative agricultural systems.

- Seventh, field-level comparisons are not sufficient and a wider systems perspective is needed to model the socio-economic and institutional factors affecting the feasibility of broader adoption and up-scaling.
6 Institutional and policy context

Having presented a conceptual framework to compare farming systems, and having reviewed the empirical literature on such comparisons, the next question is how a change can be affected towards the desired outcome of sustainable farming systems? The institutional and policy context becomes just as much a focus of research, analysis, modeling and engagement as the biophysical and socio-economic context that supports the sustainable agriculture and food system. It is conducive to not only be aligned with emerging policy debates, but also be aware of the complex inter-sectoral response required for supporting sustainable agriculture, and how to develop a supporting process and framework that will enable different sectors and stakeholders to better coordinate their work. The focus of this section is to provide insight on what is required from an institutional and governance perspective in achieving more sustainable agriculture and food systems. Where in the agriculture and food system are policy interventions required? And, if such interventions are required, what type of policy instruments are the most appropriate?

6.1 Institutional arrangements

Institutions can be defined as the set of formal and informal rules of conduct facilitating governing relationships between actors. Formal arrangements include laws, contracts, political systems, organisations, markets, etc.; while informal arrangements include norms, traditions, customs, value systems, religions, sociological trends, etc. (Kherallah & Kirsten 2002; North 1990). The large potential for institutional economic analysis to South African food and agricultural policy context has been pointed out before (Kherallah & Kirsten 2002).

South Africa is characterised by a strongly defined dual agricultural economy. On the one hand, there is highly-concentrated food production by contract farmers for agri-processing companies focused on modern urban markets (Sautier et al. 2006) and on the other hand there are extensive smallholder farmers. Smallholder cooperatives suffer from institutional problems stemming from poorly defined property rights, as well as many governance problems (Chibanda et al. 2009). Delgado (1999) suggested better vertical integration of smallholders with processors and marketers for higher value agricultural products. However, there are many institutional challenges associated with increased contract farming for smallholders (Fréguin-Gresh & Anseeuw 2011).

Institutional arrangements in the South African agricultural sector are generally characterised by weak governance and governance structures, resulting in poor/fragmented implementation of existing programmes (DAFF/IGDP 2012). Factors that contribute to poor governance relate to lack of capacity, lack of accountability, lack of comprehensive and integrative planning as well as lack of enforcement. Innovation is hampered due to inadequate institutional arrangements relating to optimal delivery on social, economic and natural sciences (DAFF/IGDP 2012). More effective governance in the agricultural sector has been earmarked as a key objective by the South African government. Specific objectives are to improve government systems and service delivery, to strengthen institutional arrangements and the regulatory framework, and to improve governance through monitoring and evaluation (DAFF/IGDP 2012).
6.2 Laws and policies

6.2.1 South African Constitution

The Bill of Rights enshrined in South Africa’s Constitution (Act 108 of 1996) stipulates that everyone has the right to access to sufficient food and water and that every child has the right to basic nutrition, shelter, basic health care services and social services (Section 28). As the Constitution is considered the supreme law of the land, it cannot be superseded by any other governmental action. Despite this, the South African government has struggled for over two decades to adequately define the right to food and to develop a comprehensive legal and policy response to the issue. Policies dealing with the right to food, loosely arranged to address the elements of food security, have remained in silos and sometimes in contradiction to each other. Key to this has been an ineffective and weakly conceptualised multi-sectoral coordination mechanism to enable an effective response to food insecurity.

6.2.2 Agricultural policy

In terms of food availability, the various policies around agriculture are important to understand. Since 1994, policies in agriculture have had three main focus areas in common, namely improving competitiveness of commercial agriculture in a free market dispensation, improving participation by the disadvantaged communities, and protecting the natural resource base. A land reform programme was initiated in 1995 (including restitution, redistribution and tenure reform), and a new agricultural policy (White Paper on Agriculture) was approved in 1996. In 2001, the Strategic Plan for South African Agriculture was signed. A review of this plan in 2008 indicated that many of the proposed goals had not been adequately addressed due to the slow pace of implementation, the limited capacity within government to implement many of the programmes and the limited coverage and inadequate funding of critical programmes. The review team also found that inadequate leadership in directing the Strategic Plan with a focused sense of urgency and commitment and implementation capacity (institutional and management capacity and skills), as well as the lack of a comprehensive implementation plan, were contributing factors. The poor performance of the agricultural sector required new perspectives on a strategy for the sector.

The Integrated Growth and Development Plan (IGDP) for the Department of Agriculture, Forestry and Fisheries (DAFF) was completed in 2012. This sought to optimise the effectiveness of previous and existing policy frameworks governing the three sectors and fast track the implementation thereof, in accordance with the encompassing national goals outlined in the Medium Term Strategic Framework of 2009 and other cross-sectoral policies. In addition to equity and transformation, equitable growth and competitiveness, and environmental sustainability included in previous plans, governance is included as an additional key challenge, which is fundamental to identifying and implementing the interventions necessary to meeting the various challenges. As part of the IGDP’s key strategy of ‘equitable growth’ specific attention is given to food security. The challenge is that while South Africa may be food secure as a country, large numbers of households within the country remained food insecure.

The most recent Strategic Plan for DAFF (2012/2013 to 2016/2017) is aimed at providing an effective framework to address the challenges facing agricultural sectors and to set the delivery
targets for the departmental programmes from 2012 to 2017. The six programmes of the plan include: Administration; Agricultural Production, Health and Food Safety; Food Security and Agrarian Reform; Economic Development, Trade and Marketing; Forestry and Natural Resource Management; and Fisheries Management. Programme 3 focused on Food Security and Agrarian Reform facilitates and promotes household food security and agrarian reform programmes and initiatives targeting subsistence and smallholder producers. It comprises three sub-programmes, namely Food Security, Sector Capacity Development, and National Extension and Support Services. The sub-programme: Food Security provides a national framework to promote the Sustainable Household Food Security Programme through the coordination of governmental food security initiatives. It is emphasised that the concept of food security remains largely embedded within a food availability paradigm, with little conceptualisation about how these relate to other directorates in DAFF let alone other sectors within government. This remains the pervasive weakness in government policy focused on food security.

The most recent policy directive to (begin to) emerge from DAFF is the Agricultural Policy Action Plan (APAP). This was approved in July 2013 by Cabinet to facilitate economic growth in favour of employment and food security. The APAP seeks to provide a long-term vision of the agricultural sector and more focused interventions in five-year rolling cycles. It is underpinned by the IGDP, which emphasises equitable growth and competitiveness, equity and transformation, governance, and environmental stability. These speak to the potential of the agriculture sector to create massive employment opportunities that have not materialised to date with job-shedding a major characteristic of the current agrarian system. This is part related to the increasing average farm sizes and mechanisation of the system based on agri-business models. This is despite the increases in production; comparing the five-year period of 2008–2012 to that of 1991–1995, field crop production increased by 28% in volume, horticulture production by 61% and animal production by 30%. Over the same period, net farm income increased by 93% on an inflation-adjusted basis. As such, the APAP argues for the need to find a better balance between large-scale and small-scale subsectors to broaden market participation and thereby increase labour absorption.

The APAP emphasises a shift away from implementing large numbers of “small” projects, as has been the practice at DAFF, to favour longer-term commodity-based strategies that has at its heart smallholder farm development. It argues that the support of smallholder agriculture is not an emotive issue but one based on solid economic arguments grounded on global evidence. A number of sub-strategies are put forward including the promotion of local food economies as a means of creating marketing efficiencies, lowering food prices and stimulating local production as well as investment into agro-logistics including the rehabilitation of freight rail for transport of bulk agricultural commodities. The promotion of import substitution and export expansion through concerted value chains is another key aspect.

Although there is real promise within the APAP to shift the existing food system to one that is more equitable and efficient, with the potential for more sustainable technologies within the drive to support smallholder farmers, it does have a number of assumptions that are echoed within the National Development Plan (NDP), which has become the overarching development agenda for government. The NDP identifies agriculture as a primary economic activity in rural areas with the potential to create one million new jobs by 2030. The plan also proposes a number of approaches to land reform and its financing. However, Chapter 6 of the NDP, although not explicit, is geared towards large-scale irrigation farming, fuel-based mechanisation, mono cropping, and export-
oriented and agro-chemical industrial agriculture. In other words, the needs and priorities of small-scale farmers, especially women, are not emphasised; instead, the current industrialised, market-based model is preferred. The transformation of agriculture to meet the needs of at least 2.5 million households in South Africa practising smallholder and subsistence farming requires different models.

The APAP, to its credit, argues that in order to support the sustainable management of natural resources within the agricultural system, an ecosystem-based management approach will be adopted. This highlights the conservation planning process aimed at conserving key natural resources and adopting a number of “well-developed” approaches to do so, many described as “climate-smart agriculture”. It takes a non-prescriptive view of these and encourages a broad use of different technologies.

6.2.3 Food security and nutrition policies

The Integrated Food Security Strategy (IFSS), endorsed by the South African Cabinet in 2002 after years of drafting, arguably failed due to an over-emphasis on agriculture (food availability) and inadequate institutional arrangements to align and coordinate related activities and programmes of government (Drimie & Ruysenaar 2011).

Drimie and Ruysenaar (2010) identified five major institutional constraints that limited the success of the IFSS. Firstly, the government department appointed to coordinate and facilitate the integrated strategy inside government failed to do so in a comprehensive fashion, as it focused primarily on developing the agricultural sector to underpin food availability rather than focusing on this and the necessary linkages with accessibility and utilisation. This led to a “bias” in the food security response to focus on agricultural production. Secondly, the coordination of food security was tasked to a directorate within a government department that did not have much administrative capacity. As such the directorate had no mechanism to drive the process or recourse to ensure that other departments, let alone directorates in its own organisation, worked within the strategy. Although the department elevated food security within its structure and hierarchy in 2012, the emphasis remained on agriculture and linkages with other sectors remained vague. Thirdly, there were no dedicated funds for government to spend on food security, at all administrative levels. All budgets were allocated by sector, preventing the emergence of joint projects and programmes, funded by one entity. Fourthly, stakeholder dialogue with civil society and within government was minimal. This remained a pertinent challenge. Finally, the absence of a Food Security Policy or legislative framework prohibited government from providing a clear line of authority as well as means of enforcing non-collaboration and implementation of relevant programmes in a disjointed manner.

Looking broadly across the discrete programmes that allegedly comprised the IFSS, a number of areas remained weak: inadequate safety nets and food emergency management systems; lack of knowledge and resources to make optimal food choices by citizens for nutritious safe diets; lack of optimal use of land; limited access to processing facilities or markets; climate change and its associated impacts; ecosystems and goods systems being undermined; and the lack of sustainability.

The draft Food Security and Nutrition Policy for South Africa, surfacing without legal endorsement in 2013, aimed to serve as a key pillar to achieving the objectives of the National Development Plan. The document defines food security as “...the right to have access to and
control over the physical, social and economic means to ensure sufficient, safe and nutritious food at all times, in order to meet the dietary requirements for a healthy life”. This echoed the definition of the IFSS and the 1996-definition of food security emerging at the World Food Summit, of which South Africa was a signatory. When defining food security the draft policy specifies four specific dimensions, which are also the determinants of food security by the policy, namely 1) adequate availability of food, 2) accessibility (physical, social and economic), 3) utilisation, quality, nutrition and safety of food, and 4) stability of the food supply.

The draft Food Security and Nutrition Policy strongly recommend inter-sectoral coordination and a real integration of existing policies. The policy is proposed to be guided, motivated and lead by the Presidency, with each element championed by a specific Ministry, supported by various other Ministries and Departments. Nonetheless, a serious limitation of this draft policy exists: although the draft policy provides some clarity in terms of a focus on food security, its official status and drastically inadequate consultation in drafting it, relegate it to insignificance in terms of providing real policy direction or emphasis in the country.

However, since democratisation of the country, several nutrition intervention programmes have been implemented under a comprehensive national nutrition strategy for combating malnutrition, namely the Integrated Nutrition Strategy (INS). The INS has three components: 1) a health facility-based component, 2) a community-based component and 3) a nutrition promotion component. The INS was used as the basis for the development of the Integrated Nutrition Program (INP), which adopted United Nations Children Funds (UNICEF’s) Conceptual Framework on malnutrition and targets nutritionally vulnerable communities and groups, including children under five years.

The Primary School Nutrition Programme (PSNP) was one of the lead projects initiated in 1994 as part of the INP, but was transferred from the Department of Health to the Department of Education in 2004 with a subsequent name change to the National School Nutrition Programme. To further address micronutrient status, the INP focuses on fortification of staple foods. Salt iodisation has been mandatory since 1995, and since 2003 it has been mandatory to fortify all maize meal and wheat bread flour with iron, zinc, vitamin A and the B-vitamins. In 2009 the vitamin A supplementation programme was extended to include national vitamin A campaign in September of each year and a new policy on zinc supplementation was implemented in 2010.

A Roadmap for Nutrition for South Africa is currently being developed by the National Department of Health based on recent reviews on the INP as well as a Landscape Analysis (WHO 2010), and seeks to direct nutrition-related activities in the health sector to achieve the four focus areas of the Negotiated Service Delivery Agreement (NSDA). It provides a framework for the repositioning of nutrition and nutrition-related issues and action, with particular reference to Strategic Plan for Maternal, Neonatal, Child and Woman’s Health, and Nutrition in South Africa (Department of Health 2013).

### 6.3 Policy implementation and challenges

Existing policies and interventions that aim to alleviate food insecurity have been fragmented and generally narrowly linked to the work of specific departments. These include agricultural credit and production programmes by DAFF, the National School Nutrition Programme by the
Department of Basic Education, the Integrated Nutrition Programme by the Health Department, and the Department of Social Development’s “food for all” programme and “Zero Hunger” campaign (taken over from DAFF).

The shortcomings or limitations of the state’s response to hunger soon become evident when reviewing their implementation. The School Nutrition Programme has been significantly expanded to include all learners, instead of targeting only the poorest in quintile one to three schools, and now includes secondary schools. But the programme only provides meals for 190 days a year, which does not address nutrition comprehensively. The Integrated Nutrition Programme, as described above, is made up of several initiatives, including food fortification and vitamin A supplementation. Similarly, this programme makes an important contribution but is inadequate and lacks a systematic, co-ordinated effort and proper monitoring. The IFSS, as argued, was the first attempt by the government to formulate a national plan to address the components of food security and the need to co-ordinate the role of government departments. Yet the strategy, under DAFF, has been criticised for being driven primarily by a focus on production and rural development. Despite this, the National Development Plan places food security under the chapter on rural development and does not go far enough to frame food security beyond production, health and rural development.

The challenge of addressing food insecurity and hunger in South Africa is widely recognised as inherently complex and the department largely responsible (i.e. DAFF) is poorly equipped, both administratively and conceptually, to deal with the interlinked priorities of poverty and hunger. Again, as argued above, the 2013 draft national policy on food and nutrition security is the current reference point for co-ordinated government work on food security, serving as a successor to the integrated food security strategy, but remains largely void of content. One of the major reasons South Africa falls short of addressing food insecurity in a comprehensive manner is, in part, because food insecurity is not a technical issue that can be addressed by programmes run by existing departments. It requires a more co-ordinated approach that has both political will and resourcing, including elements of immediate and direct relief, and structural and institutional change that addresses distribution problems in the food system.

These issues, although technical in many respects, relate to an argument made by Kirsten (2012) that no real substantive changes in government food and agricultural policy has occurred after 2002 that has effectively addressed the situation. If food security, largely recognised as being an issue of escalating food prices affecting the poorest South Africans and the nutritional dimension of this, were a political priority then surely these issues would have been addressed? Kirsten (2012) argued that a lack of coherence can partly be explained by a lack of urgency to address food prices (food security) despite acknowledging that the poor will be negatively impacted by the increase in food prices. This argument is substantiated by reference to the National Treasury’s rejection of the possibility of introducing any form of price controls or any other form of government intervention in the market economy.

A key question is thus how the various programmes that fall within a comprehensive food policy would be implemented in practice and if the necessary human capacity and structure is available. Clear targets, outcomes and indicators are also imperative to ensure joined-up planning. A key dimension is that joined-up government must be seen in a financial context where the fiscal control and oversight of the National Treasury have to be adhered to (Drimie & Ruysenaar 2010). These arrangements do not easily allow for a “blurring of funds” to be used in joint projects. Calland (2007:54, as cited in Drimie and Ruysenaar, 2010) quoted an insight of the late Kader
Asmal that “…as an attempt to strengthen ‘joined-up government’, unless budget is allocated to the clusters - which it isn’t - then it can’t be ‘joined-up’ decision-making”. Current mechanisms to reorganise funding continue to be problematic given the need for stringent accountability of government spending.

The biggest problem with the implementation of current agricultural and food policies is the total absence of any coordination mechanism and the duplication of efforts and programmes. Since food security and improved rural livelihoods are some of the Presidential outcomes every department tries to build in these elements in their strategic plans and programmes. The result is that there is duplication of effort and often people with limited expertise in food security, agriculture and nutrition are appointed to lead these initiatives in departments such as Human Settlement, Rural Development, Public Works, etc. This generally leads to poor implementation and a waste of valuable state resources. The issue of coordination and the efficiency in delivery of actions and programmes remains one of South Africa’s major challenges.

In 2010, the Diagnostics Report of the NPC identified a failure to implement policies and an absence of broad partnerships as the main reasons for slow progress in South Africa. As part of the solution, the NDP, Vision 2030, was developed to align future activities of the country at policy level, with the main aims to eliminate poverty and reduce inequality in the next three electoral periods. Affordable access to quality healthcare as well as household food and nutrition security are listed as milestones to achieve the aims proposed by the NDP, Vision 2030. Environmental sustainability and women empowerment are also highlighted in the NDP.

The institutional design to reach this vision should aim at creating enabling frameworks for partnerships, effective coordination and alignment of activities. This must involve clarity on how different departments operating within different structures and at different levels will coordinate their programmes. Further the programmes designed to implement this policy should articulate with community-level planning processes with adequate budgets to ensure such partnerships are supported. Cousins (2011) has argued that such processes entail bureaucracies adopting the characteristics of learning organisations that embrace inevitable errors as a source of important information, rather than denying them or being overwhelmed by them.

Taking this further, the interactions with communities by their very nature demand a flexible, learning approach that prioritises the process as much as the outcome. This is a different approach to the “modernist” tendencies of government departments and raises the real challenge of the NDP: how to activate citizenship and be a responsive government. Advocacy is thus a critical element of any effort to raise the policy profile and social consensus for food insecurity, and to highlight both the human and economic development benefits. Policy-makers will not generally increase the resources allocated to activities that enhance food security without external pressure; the motivation must come from elsewhere. As such a champion that transcends sectors is sorely required to drive this process.

Many challenges remain, some of which seem intractable. A key issue is the way government is structured, the subsequent sector-specific resource flows, and evaluation and incentive arrangements. Benson (2011a, as cited in Harris and Drimie, 2012) argued that there are good reasons for the sectoral structure of government, but this does have the unfortunate effect of not being sufficiently flexible to effectively address issues that do not fit neatly into the structure, with food insecurity being one such issue. A lack of human resources and capacity for nutrition and food security programming is another key issue, constraining the implementation of even the most strategic and well-resourced programmes (Swart et al. 2008). Staff at local levels often do
not possess the knowledge and skills needed to design and implement adequate interventions in various sectors, and often do not received adequate guidance from the national level. Another major issue is the top-down nature of planning processes in most government departments and certainly in Agriculture, Health and Rural Development.

The underlying rationale, purpose and organisational processes of different sectors make multi-sectoral cooperation a challenging strategy in terms of design and implementation. Departments often have different definitions of targets such as smallholder farmers or production units, and indicators that are used are different despite using the same terms. This also raises the question about the need for clarity on which department has the requisite authority to enforce alignment and coordination supported by adequate monitoring frameworks.

Put simply, South Africa needs better-coordinated and planned food security and nutrition interventions. Advocacy to raise the policy profile and social consensus for nutrition is essential. A collective vision to implement nutrition and health outcomes in agriculture is required, as identified in the NDP, Vision 2030.

### 6.4 Policy instruments

The main institutional and policy changes that have been implemented since 1994 in South Africa include the closure of marketing boards and the agricultural credit board, the abolition of certain tax concessions and a reduction in direct input subsidies, the introduction of new labour legislation and the start of a land reform process, as well as R&D services to emerging farmers (OECD 2006). There were no direct interventions on domestic markets to support producer prices since 1996. The most important change for field crop commodities was the abolition of pan-territorial and pan-seasonal pricing mechanisms in favour of differential prices across regions and across time. The livestock sector has seen an increased vertical integration in the supply chain in response to deregulation policies, as well as a rise of meat sold in informal markets. Reforms in the horticulture sector has seen the abolishment of a statutory monopoly handling all exports and many marketing and export agents have since entered the market. Input subsidies have been reduced, notably the abolishment of large-scale drought relief by government, and the reduction of implicit subsidies on capital equipment. However, capital improvements on farms are still tax deductible and, as from 2001, fuel tax rebates has been applied. Interest rate subsidies have been removed and replaced with institutions providing micro credit and better access to formal financial markets. The need for environmentally-friendly farming practices has been recognised, but the underlying pretext is that resource conservation comes at the farmers’ own cost. Trade tariffs have generally been reduced, and no export subsidies are applied, with the notable exception of the sugar industry. The agricultural sector is further excluded from carbon tax for the first 5 years of the programme (National Treasury 2013).
7 Discussion and way forward

In this section we present the areas in need of further study, suggest an appropriate modeling framework to inform questions on the form sustainable agriculture could take in the country, and outline policy processes and interventions needed to steer towards sustainable agriculture in support of green economic development.

7.1 Sustainable agriculture system modelling

The next step would be a comparative analysis between conventional and alternative systems based on empirical results from field trials around the country as well as the best available understanding of the current agricultural and food system in the country. A system dynamics model would be able to capture the dynamic interrelationship between system components and provide the means to simulate the most likely range of outcomes as measured in terms of a multiple set of indicators for alternative systems over a predefined time period. Monte Carlo techniques would help to define the uncertainties associated with such simulations (see Crookes et al. 2013).

Based on this review, Box 2 contains suggested components that need to be included to model the differences between conventional and alternative sustainable agriculture and food systems in South Africa. High-level interrelationships between the various components are indicated. The high-level systems components include: the natural environment, the markets, the farming production system, the food system including nutritional quality, and the institutional context. Box 3 provides a number of elements that could form part of each of these high-level components. For example, the natural environment interfaces with the agricultural system in at least three areas: water use, land use and energy use. (See also De Wit and Crookes (2013)).
Box 2  Interrelationships among various components

MARKETS
Prices, Distribution costs, Post -harvest losses, Agricultural products, Other products, Food exports, Food imports, Consumers

FARMING SYSTEM
Production systems
Maize, Citrus, Beef
Production inputs
Fertilizers, labor, capital, agrochemicals, etc.
Production volumes

FARM MANAGEMENT
Maize farming systems
CV, NT, CA, LEI, organic
Citrus farming systems
CV, organic
Beef farming system
CV, CA, organic

FOOD SECURITY & NUTRITIONAL SYSTEM
Food availability
Production
Food utilisation
Consumption
Access to food
Value chains
Stability
Consumer price
Nutritional quality
Pesticide residues, Antioxidants, Toxic Metals, Antibiotic residue bacteria,

NATURAL ENVIRONMENT
Land, Water, Energy
Precipitation, temperature
Effects on erosion, Soil organic matter, Soil organic carbon, biodiversity, Eutrophication, Emissions, Acidification, etc.

GOVERNMENT
Policy instruments: Taxes, Fuel tax rebate, Drought relief, Input subsidies, Tariffs; Micro -credit, Tax deductions, Carbon tax
## Box 3 Constituents of each component

### 1. Spatio-temporal scales
- Province
- Regions
- Farm levels
- Time period
- Time step
- Biome (or finer conservation scale)
- Landscapes (link to biodiversity)
  - Intensive farming
  - Small-scale

### 2. Farming system
- Farm management (link to Farm management)
- Field crop types
  - Maize crop types
- Horticulture types
  - Citrus types
- Livestock types
  - Beef types (Nguni)
- Environmental inputs (link to natural environment, resource use)
- Fertiliser volume
- Fertiliser cost
- Capital costs (incl. debt amount, interest rate, debt terms)
- Employment number
- Labour costs
- Marketing costs
- Production volume (link to food system)
- Producer price
- Net profits/loss (calculated)

### 3. Food system
- Production (link to farming system; availability of food)
- Consumption (link to utilisation of food)
- Net imports (imports minus exports)
- Consumer price
- Food waste
- Pollution indicators

### 4. Value chain (link to access to food)
- Institutional arrangement indicators
- Post-harvest losses
- Distribution costs

### 5. Food security and nutritional system
- Food availability (link to production, trade, value chains)
- Utilisation of food (link to consumption)
- Access to food (link to value chains)
- Stability (link to consumer price)

### 6. Nutritional quality
- Pesticide residues
- Antibiotic residue bacteria
- Antioxidants
- Toxic Metals

### 7. Natural environment (link to farming systems)
- Precipitation
- Temperature
- Climate variability
- Soil organic carbon
- Soil organic matter
- Biodiversity
- Nitrogen leaching
- Nitrous Oxide emissions
- Ammonia emissions
- Eutrophication potential
- Acidification potential
- Greenhouse gases

### 8. Natural resource use (link to farming systems)
- Water use
  - Irrigation
  - Rainfall
  - Groundwater
- Land use
- Energy use
  - Diesel use
  - Diesel price
  - Electricity use
  - Electricity price

### 9. Institutional arrangements
- Ownership types
  - Commercial farmers
  - Smallholders
  - Emerging farmers
  - Communal farmers
  - Subsistence farmers
- Market access
  - Contract farmers (link to commercial farmers; smallholders, value chain)
  - Other markets

### 10. Farm management
- Farming technologies for maize
  - Conventional tillage
  - No-tillage
- Conservation agriculture
- Organic CA
- Farming technologies for citrus
- Farming technologies for beef
- Management practices

### 11. Policy instruments
- Fuel tax rebate
- Drought relief
- Input subsidies
- Tariffs
- Micro-credit
- Tax deductions
- Carbon tax
7.2 Sustainable agriculture and the green economy

Can the production of sufficient, healthy food in an environmentally sustainable manner be conducive to economic growth and development in South Africa? Can the protection and conservation of natural resources be a driver of the green economy?

The main options need to be identified and tested in a South African context and the following suggestions serve as a starting point:

- Improve land and water management
- Increase yields on unproductive farms
- Address barriers to entry for smaller-scale farmers
- Shift to degraded lands
- Food value chains need to reduce losses during distribution and storage
- Minimise post-consumption food waste
- Shift to different diets
- Invest in research and innovation systems

Agriculture must become more multifunctional and policy support is needed towards the joint production of agricultural commodities and ecological services. This means to invest in knowledge to evaluate such multi-functional systems (Jordan et al. 2007).

7.3 Institutional and political change

A strong argument can be made that one of the biggest challenges facing the implementation of current agricultural and food security policies – and therefore the success of sustainable agricultural and food systems in South Africa – is the absence of effective coordination mechanism that can align different responses across sectors. A key question, therefore, is how to elevate the issue of coordination and alignment to address sustainable food systems in the list of complex issues facing government? Similarly, how can the limited engagement and participation of civil society and the private sector be addressed?

Multisectoral cooperation can build organisational and institutional capacity for innovative and large-scale sustainable change such as is required to address food systems. Initiating cooperation requires significant resources – time, energy, funds and skills – and managing these relationships requires considerable resources. If carried out carefully, however, the pay-offs are significant, including finding solutions to difficult yet important development problems such as food insecurity, triggering catalytic or multiplier effects, fostering sustainable change, and creating multisectoral social capital that promotes new local capacity for joint action.
7.4 Informing further research and methods

Further empirical research is clearly required on alternative farming systems. The results worldwide point towards the importance of specific contexts in the success of alternative farming systems. Furthermore, system changes in farm management require trade-offs in allocation of resources at a farm-level and cannot be solved without larger-scale interventions that address broader socio-economic and institutional arrangements. A knowledge base, not only on the farm-level, but also across agricultural and food value chains is needed to support required innovations. Participants from multiple academic disciplines as well as non-academic participants are needed for research on system comparisons and to hasten the implementation of more sustainable agricultural systems (Reganold 2013).
8 Summary and conclusions

The South African agricultural strategy needs to empirically test alternative forms of sustainable agriculture as central components of the green economy and to identify options that would deserve intervention. This report provides a baseline review on progress made on sustainable agriculture in South Africa so far. It serves as a resource document for the development of an appropriate comparative modeling framework to inform questions on sustainable agriculture in the country and outlines policy processes and interventions needed to steer towards sustainable agriculture to support greener economic development.

Before a path towards more sustainable agriculture can be outlined, further investment in knowledge on multi-functional agricultural systems is needed. The main options for improving the sustainability of agriculture that need to be tested for various agricultural systems in a South African context are the following:

- improving land and water management
- increasing yields on unproductive farms
- addressing barriers to entry for smaller-scale farmers
- shifting to degraded lands
- reducing losses during distribution and storage in food value chains
- minimising post-consumption food waste
- shifting to different diets
- investing in research and innovation systems

Further empirical research is clearly required on alternative farming systems, as results worldwide point towards the importance of specific contexts in the success of alternative farming systems.
References


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Ziervogel, G. & Ericksen, P.J. 2010. Adapting to climate change to sustain food security. WIREs Climate Change, 1(July/August):525–540.
## Appendix 1  Defining sustainable agriculture: a comparative analysis of various terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Other terms</th>
<th>Key words/principles</th>
<th>Criticism</th>
<th>Key issues/principles/description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainable agriculture</td>
<td>“greener economy” The ability of an ecosystem to function and maintain productivity for a prolonged period</td>
<td>A collective name for different (more nature-based) approaches to farming? An overarching concept referring to several agricultural management systems and farming principles Sustainable Agriculture (SA), which is defined by Fowler and Rockstrom (2001:93) as, the use of agricultural practices which conserve water and soil and are environmentally non-degrading, technically appropriate, economically viable and socially acceptable. (Du Toit 2007).</td>
<td>Too widely defined. No consensus on each sub tool/concepts/principles.</td>
<td>Modern “sustainability” definitions refer to the triple bottom line of social/environment/economic issues addressed simultaneously. Socially acceptable, economically viable and environmentally sound Sustainable agriculture is the efficient production of safe, high quality agricultural products, in a way that protects and improves the natural environment, the social and economic conditions of farmers, their employees and local communities, and safeguards the health and welfare of all farmed species.</td>
</tr>
<tr>
<td>Natural farming</td>
<td>“Do nothing farming”, Fukuoka method, no-dig gardening Related to fertility farming, nature farming (&quot;no fertiliser&quot; farming), organic farming, sustainable agriculture, agro-forestry, eco-agriculture and permaculture but should be distinguished from biodynamic agriculture.</td>
<td>1. no tillage 2. no fertiliser 3. no pesticides herbicides 4. no weeding 5. no pruning ground cover/mulch (cover crop), minimizes human labour, Promotes avoidance of manufactured inputs</td>
<td>It emphasized small scale operations and this questions the applicability of this approach a highly mechanized farms</td>
<td>No human supplied inputs and mimics nature. Natural farming approach is established by a Japanese farmer and philosopher: Masanobu Fukuoka (1913-2008)</td>
</tr>
<tr>
<td>Agroforestry</td>
<td>The incorporation of trees into crop and livestock farming systems. Contribution to key indicators such as biodiversity, productive capacity, ecosystem health, soil and water maintenance, carbon contribution, socio-economic benefits, and legal frameworks Or other way around use crops in forestry and orchards (i.e. citrus)</td>
<td>Issues of scale application?</td>
<td>Agroforestry is the system of developing agricultural land in combination with forestry technologies. Through this system, land with shrubs and trees are used to also grow crop and livestock to encourage health, profitability, productivity, diversity, and sustainability. There are numerous benefits to agroforestry as it encourages the adaptation of natural ecological processes within the commercial system. It helps farmers in terms of controlling land degradation, sheltering crop and livestock, improving their landscape, and enhancing wildlife habitat while making the most out of commercial opportunities. All that can be done through sustainable agroforestry without the use of complicated machinery and man-made technologies that can be expensive and also have the potential to produce unnecessary waste. Agro-forestry can provide at least some of the biodiversity required by conservation agriculture systems, including possibly ‘living fences’. Fowler 2004. Hobbs (quoted in Fowler 2004:33) commented: Agro-forestry initiatives such as planting trees on higher and steeper slopes would be promoted. Use of living fences and stabilized contour bunds using various legume plants/shrubs or grassy plants would help with erosion and through pruning.</td>
<td></td>
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<tr>
<td>Rain water harvesting</td>
<td>ARC ISCW at Glenn (close to Bloemfontein) have developed water harvesting systems. These advocate maintaining 2/3 of the land bare with no soil cover, to promote runoff to the lower third of the strip (3 m wide).</td>
<td>Although possibly effective for small scale water capture, the temperatures generated under bare soil and its exposure to rain drops make this system probably less sustainable than conservation agriculture (Dersch 2004).</td>
<td>Also look at work of Prof van Rensburg from UFS and Water Research Commission from Pretoria</td>
<td></td>
</tr>
<tr>
<td>Eco-agriculture</td>
<td>Ecological farming? Integrated landscape management</td>
<td>Eco-agriculture simply holds that to be economical, agriculture must be ecological</td>
<td>Is tillage used as a weed control strategy?</td>
<td>Eco-agriculture is an approach to managing landscapes to meet three goals: i) conserve biodiversity and ecosystem services, ii) provide agricultural products sustainably and iii) support viable livelihoods for local people. It promotes soil building countering the conventional farming, which is seen as soil mining strategy</td>
</tr>
<tr>
<td>Biological farming (BF)</td>
<td>Linked to Albrecht soil testing method “feeding the soil” farming “hands-on agronomy” BF promotes No-till/Conservation Agriculture as it helps in soil restoration and soil mineral balancing.</td>
<td>Biological farming is based on balanced soils with soil mineral corrections More nature-based. Keywords: legumes-based pastures and incorporating legumes in crop rotations. It is about soil health and balancing of soil nutrients. Ley crops (using grass in cropping systems) fit in with Conservation Agriculture</td>
<td>Although many would not be offended by biological farming many scientists oppose the Albrecht System of soil Mineral Correction as non-scientific</td>
<td>There is apparently a correlation between NT/CA farmers in South Africa and Australia that lean towards using the Albrecht system of soil mineral correction, despite criticism of conventional soil scientist. In SA look for work of John Fair and international for work of Gary Zimmer, Neal Kinsey and Charles Walters</td>
</tr>
<tr>
<td>Biodynamic agriculture</td>
<td>Anthroposophy (a philosophy founded by Rudolf Steiner, postulates the existence of an objective, intellectually comprehensible spiritual world accessible to direct experience through inner development.</td>
<td>Biodynamics is a spiritual-ethical-ecological approach to agriculture, food production and nutrition. Biodynamic farmers strive to create a diversified, balanced farm ecosystem that generates health and fertility as much as possible from within the farm itself. Biodynamic practitioners also recognize and strive to work in cooperation with the subtle influences of the wider cosmos on soil, plant and animal health. Biodynamics is thus not just a holistic agricultural system but also a potent movement for new thinking and practices in all aspects of life connected to food and agriculture</td>
<td>Most biodynamic initiatives seek to embody triple bottom line approaches (ecological, social and economic sustainability).</td>
<td></td>
</tr>
<tr>
<td>Organic agriculture</td>
<td>A good working definition is provided by the International Federation of Organic Agriculture Movements (<a href="http://www.ifom.org">www.ifom.org</a>): Organic agriculture includes all agricultural systems that promote the environmentally, socially and economically sound production of food and fibres. These systems take local soil fertility as a key to successful production. By respecting the natural capacity of plants, animals and the landscape, it aims to optimise quality in all aspects of agriculture and the environment. Organic agriculture dramatically reduces external inputs by refraining from the use of chemical, synthetic fertilisers, pesticides, and pharmaceuticals. Instead it allows the powerful laws of nature to increase both agricultural yields and disease resistance.</td>
<td>Low(er) yields (Tuck et al. 2014), De Ponti et al. (2012): Organic yields of individual crops are on average 80% of conventional yields, but variation is substantial labour intensive, El-Hage Scalabba and Hattam (2002) Allows tillage-based operations Lack of uniform certification standards and difficulty of monitoring standards. The producer is not ready or interested in organic farming due to the dominance in economic interest over environmental interest (McDermott 2013).</td>
<td>Organic agro-production refers to agriculture which does not use artificial chemical fertilizers and pesticides, and respect animals lived in more natural conditions, without the routine of using drugs or antibiotics, common in the intensive livestock farming. The most commonly reasons for consuming organic food are: food safety, the environment, animal welfare, and taste (Soil Association, 2003). The principal environmental reason for localizing food supply chains is to reduce the impacts of food miles—the distance food travels between being produced and being consumed —and to reduce the energy and pollution associated with transporting food around the world. Local food is a solution to the problem of food miles (Vintila 2011).</td>
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</tbody>
</table>
**Permaculture**

- Mimic nature integrated design system that's modelled on nature.
- Permaculture is the conscious design and maintenance of agriculturally productive systems which have the diversity, stability, and resilience of natural ecosystems. It is the harmonious integration of the landscape with people providing their food, energy, shelter and other material and non-material needs in a sustainable way. An ethical philosophy of earthcare & peoplecare supported by the distribution of surplus goods; wealth, labor, attention, information
- Permaculture really starts with an ethic or earthcare, understood as care of whole systems of earth & species. So we actually devise model systems. Much of the design is drawn from nature. The end result that we aim for, is to produce a system that is ecologically sound & economically profitable. It can get sophisticated or be as simple as you like.

**Regenerative agriculture**

- In the true sense of the word it means to rejuvenate the soils/land etc.
- Regenerative agriculture refers to all the efforts beyond the farmer’s productive functions to promote holistic vision, role and importance of farmers; encourage stewardship; transitioning farmers. In short: promote the true importance of farmers in our societies. Also the affirmation that agriculture is an absolutely essential part of any world-wide efforts to improve our environment and health

**Precision farming**

- On-field application system (GIS/computerized system)
- No criticism as such, but precision farming can be applied under any cropping or agricultural system. It is not a farming system, but is treated as a management tool
- Precision farming should not be thought of as only yield mapping and variable rate fertiliser application and evaluated on only one or the other. Precision farming technologies will affect the entire production function (and by extension, the management function) of the farm. A brief overview of the components in precision farming is listed below. Yield monitoring, Yield mapping, Variable rate fertiliser, Weed mapping, Variable spraying, Topography and boundaries, Salinity mapping, Guidance systems (for e.g. for traffic control), Records and analyses
- Precision agriculture can be defined as a management system that is information and technology based, is site specific, and uses one or more of the following sources of data: soils, crops, nutrients, pests, moisture, or yield, for optimum profitability, sustainability, and protection of the environment. The primary benefits, both economic and environmental, result from reduced or targeted placement of crop inputs such as nutrients, pesticides and water.

**Low external input sustainable agriculture (LEISA)**

- Promote farming systems that depend on biological regulation functions reducing and eliminating external inputs
- Perhaps also a collective approach, because certain management tools and farming systems need to mentioned specifically in order to achieve LEISA

**No-tillage**

- Zero tillage
- Some people refer to strip till, mulch till, zone till, ridge till
- Moyer (2011) refers to NT without soil cover and sound crop rotations as conventional NT (CNT) as compared to NT with sound crop rotations and cover (mulch or cover crops),
- An approach to farming based on direct seeding and not tilling (inverting) the soil
- Associated with increased use of herbicides in addition, glyphosate and other herbicide resistance found in areas under LT NT cropping
- OFA (2012:28) warned against the fact that many mixture of chemicals ("cocktails") act synergistically. This means that instead of $1+1=2$, the extra effect of the mixtures can mean $1+1=60$ or even 1000 in toxicity
- No- or zero tillage is determined by the level of soil disturbance (see text below table under CA definitions)
- NT refers to soil disturbance up to 20%-25% (Govaerts et al., 2009, p. 98) by using tine- or combination tine and disc planters. Zero tillage refers to direct seeding with disc-planters (less soil disturbance than with tine; ≤20%)
- Savings on farm inputs especially fuel and maintenance of farm machinery
<table>
<thead>
<tr>
<th><strong>Farming God’s way (FGW)</strong></th>
<th>Foundations for Farming was born out of a man living in relationship with Jesus Christ and basing his life and farming on foundations found in God’s word, the Bible. Read work of Brian Oldrieve in this regard.</th>
<th>Biblically-based version of conservation agriculture. Promotes the link between agriculture, care of Creation and the role of man/humans (stewardship)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Diversification</strong></td>
<td>Seek to diversify the farm into other farming activities or possible non-farming activities if appropriate in order to increase farm income and to reduce risk linked to market price fluctuations.</td>
<td>Many farmers farm because they love their work, lifestyle and being in and around nature. Many of these farmers are not interested in increased non-farming activities which include other sets of skills (i.e. admin, marketing, and life-skill)</td>
</tr>
<tr>
<td><strong>Conservation Agriculture (CA)</strong></td>
<td>The full definition of Conservation Agriculture is provided by the UN Food and Agriculture Organization (FAO) on its website (<a href="http://www.fao.org/ag/ca/1a.html">http://www.fao.org/ag/ca/1a.html</a>). The definition further describes CA as follows: CA principles are universally applicable to all agricultural landscapes and land uses with locally formulated and adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical soil disturbance are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes. CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production. Complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.</td>
<td>CA is based on three principles applied simultaneously: 1. minimum disturbance of the soil 2. apply permanent soil cover 3. Apply sound crop rotations. Kassam et al. 2009 stated that a good crop rotation should have ≥3 crops including legumes.</td>
</tr>
</tbody>
</table>

which leans to Conservation Agriculture. See terminology below.

The move towards more GM crops make farmers increasingly reliant on profit-oriented companies (2010 AGRICULTURE FACTS & TRENDS South Africa.pdf).

Use of GM crops and certain pesticides, herbicides and fertilisers may also isolate SA from lucrative export markets (2010 AGRICULTURE FACTS & TRENDS South Africa.pdf).

Relying on single-variety crops is also risky. If these crops fail to perform, it will have a significant impact on national production (2010 AGRICULTURE FACTS & TRENDS South Africa.pdf).

Conservation Agriculture (CA) with Biblical teaching

NT with mulch retention

Direct seeding

NT cover cropping

Conservation tillage (this term might appear as the same as CA, but is not. Many publications refer to Conservation Tillage (CT) or Conservation Farming (CF), but CA is a more comprehensive concept. Conservation tillage refers to the adherence of 2/3 CA principles (see columns 4) with soil cover as from 30%. CA differs here with high quantities of soil cover – preferably 100%.

High dependence on chemicals (at least in the conversion period of No-till).

Management intensive and eco-type specific. It implies that there are no “cut-and-paste” recipes and this farming system requires new ways of thinking, management and testing and trialling. It implies that trial costs are at the farmer’s expense and act as a barrier to change in current farming with very tight gross margins

Other biological cover crop based weed control strategies are extremely difficult and site specific (MAR, soil type etc.) by eliminating non-chemical and no-tillage weed control strategies.
| **Fertility farming** | No ploughing, natural N fixation, role of compost, natural balance of nutrients
Mimic nature: Nature does not plough; she employs the earthworm and soil bacteria, together with deeply penetrating roots, to do her work. | *Fertility Farming* explores an approach to farming that makes minimal use of ploughing, eschews chemical fertilisers and pesticides, and encourages cover cropping and manure application |
|---|---|---|
| **Agro-ecology** | The definition of agro-ecology refers to the application of ecological science to agro-ecosystems. It seeks to improve agricultural systems by mimicking natural processes, thus enhancing beneficial biological interactions and synergies. | Common principles are:
- Recycling nutrients,
- Integrating crops and livestock
- Diversifying species and genetic resources
- Improve interactions and productivity throughout the agricultural system |
| **Resilient agriculture as mentioned in De Schutter, 2013.** | Climate smart agriculture (CSA) Developing agricultural systems in such a way to be more resilient to climate change shocks, abnormalities and extremes e.g. drought spells, excessive rainfall, prolonged high temperatures | No criticism as such as it is good for production systems to be more resilient, but this concept is probably a more comprehensive overarching term |

*Source: Own analysis*
## Appendix 2  Summary of CA related research conducted in RSA

<table>
<thead>
<tr>
<th>Country</th>
<th>Area</th>
<th>Research topic and details</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSA</td>
<td>All provinces</td>
<td>Conservation tillage-based agrarian revolutions in South Africa.</td>
<td>Fowler 2004:27-35</td>
</tr>
<tr>
<td>RSA</td>
<td>All provinces</td>
<td>Background and conceptual basis of NT research pre-1950, post-1950, 1988-1998</td>
<td>Fowler undated a</td>
</tr>
<tr>
<td>RSA</td>
<td>All provinces</td>
<td>The Establishment and Management of Demonstration Sites and Synthesis of Conservation Agriculture (CA) in South Africa. Promoted by National CA Task Force with members from DAFF, FAO, ARC, University of Fort Hare and others.</td>
<td>Smith et al. 2010</td>
</tr>
<tr>
<td>RSA</td>
<td>All provinces</td>
<td>This document is a summary after the CA task force meeting with a large group of stakeholders. Smith et al, 2010:5 To document, analyse and synthesise CA information in South Africa, a questionnaire (Annexure 5) was designed and sent initially to 150 individuals and groups including CA practitioners, researchers and administrators as well as, by request, to others. In total, 42 responses were received. Categories of respondents were the Agricultural Research Council (ARC), provincial departments of agriculture (6); farmers (9); farmers organisations/organised agriculture (6); NGOs (5), universities (3); and three others namely a journalist, a consultant/capacitor and a commercial company. To supplement information collected, personal interviews were held with specific stakeholders to collect further information on CA application.</td>
<td>Smith et al. 2010</td>
</tr>
<tr>
<td>RSA</td>
<td>All provinces</td>
<td>Smith et al., 2010: 39-56 provide a good breakdown of CA/NT initiatives in SA.</td>
<td>Smith et al. 2010</td>
</tr>
<tr>
<td>RSA</td>
<td>All provinces</td>
<td>Of the over 850 Clean Development Mechanism (CDM) projects registered in the world only 27 were in Africa. A real opportunity therefore exists for African Conservation Agriculture farmers to develop this market, but to do so they need to work in concert with one another and use some of the moneys generated to set up a technical advisory facility and a lobbying group. If programmes were developed which also included reward for good stewardship of the land (for example by reducing erosion), and other services to the public good (such as decreased siltation of dams and cost of water purification), a package could be devised which would not only increase the adoption of CA but be of real interest to farmers, governments and, to get them started, donors.</td>
<td>Fowler undated b</td>
</tr>
<tr>
<td>ARC/LandCare operates country-wide with CA trials at:</td>
<td>Mpumalanga at Mlondozi, KwaZulu-Natal near Bergville, and in the Eastern Cape at Lusikisiki and Bizana.</td>
<td>The ARC-Institute of Soil Climate and Water, under the auspices of and with the financial support of the National Department’s LandCare initiative, initiated conservation farming projects in Mpumalanga at Mlondozi, KwaZulu-Natal near Bergville, and in the Eastern Cape at Lusikisiki and Bizana. In contrast to the KwaZulu-Natal Department’s initiative, each of these were with a specific community and trials and demonstrations were carried out by researchers with farmers on their fields, with minimal extension involvement. This intimate relationship between farmer and researcher have led to reasonable to good levels of adoption, albeit at present in localised areas.</td>
<td>Fowler 2004</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Province</th>
<th>Area</th>
<th>Research topic and details</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gauteng</td>
<td>ARC Pretoria, Grain SA, DAFF, FAO Zeekoevlei near Pretoria trials (One of the National CA Task Force demo sites)</td>
<td>Smith et al. 2010:6</td>
<td></td>
</tr>
<tr>
<td>Limpopo</td>
<td>Mphanama village</td>
<td>Turffloop Campus, University of the Far North publications</td>
<td>Smith et al. 2010</td>
</tr>
</tbody>
</table>
<pre><code>| | Mphanama Village community Eco-technology project. (One of the National CA Task Force demo sites). This project is funded by the Limpopo Department of Agriculture. | Smith et al. 2010 |
</code></pre>
<table>
<thead>
<tr>
<th>Country</th>
<th>Area</th>
<th>Research topic and details</th>
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<tbody>
<tr>
<td>North West</td>
<td>BFAP</td>
<td>A comparative assessment between RT and NT farmers. Reduced (minimum) tillage is assumedly already the conventional way of farming. Barriers and drivers for NT adoption discussed. NT has 12% savings on gross margins as compared to RT</td>
<td>Du Toit 2007 (UP, BFAP)</td>
</tr>
<tr>
<td>Mpumalanga</td>
<td>EFS (Ficksburg, Clocolan, Ladybrand, Zastron)</td>
<td>Conservation Agriculture and Commercial Farmers in the Eastern Free State. Comparison between NT and CV globally; barriers to adoption NT; farmer trials on soil wetness, soil carbon and water infiltration rates under NT vs. CV; environmental load in GHG of production systems and gross margins</td>
<td>Knot 2014 (UFS)</td>
</tr>
<tr>
<td></td>
<td>Reitz, Tweespruit, Clocolan, Vrede</td>
<td>Commercial NT farmers organized farmer groups for applied research and creating CA platforms for the promotion of NT and CA. These initiatives are promoted by Grain SA</td>
<td>Personal communication Hendrik Smith</td>
</tr>
<tr>
<td>Eastern cape</td>
<td>Massive Food Production Scheme for smallholders in EC under CA block farming</td>
<td>And the Eastern Cape Government is planning programmes to improve rural household garden production and livestock nutrition and marketing. Hobbs (2004) noted that the challenge in this area is to slow erosion caused by over-grazing and unsustainable land management practices. This he believed will require a watershed approach with agro-forestry, soil conservation and conservation agriculture principles all playing a role in achieving increased and sustainable agricultural production. Initial emphasis on improving kitchen gardens both in terms of production and quality but also diversity is a logical step and would go a long way to providing food security and nutritional quality for the households and as an introduction to the principles of conservation agriculture (Hobbs, 2004).</td>
<td>Fowler 2004</td>
</tr>
<tr>
<td></td>
<td>CA Thrust of university of Fort Hare – N2 Lima project</td>
<td></td>
<td>Smith et al. 2010:6</td>
</tr>
<tr>
<td>PE</td>
<td>Grant Dryden and team is active around Port Elizabeth (new name) promoting Farming God’s Way. Collaboration with NWWU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>University of Fort Hare</td>
<td>Animal traction and CA (Faculty of Science and Agriculture)</td>
<td>See CAT of UFH above (Butterworth area)</td>
<td>Several guides and publications from G. Meikle (director) and B. Joubert (manager – animal traction sector)</td>
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<td>George - Tsitsikamma</td>
<td>Cover crop research</td>
<td>In the George - Tsitsikamma area some farmers have been practising no-tillage for 10 years. The main goal of these farmers is to produce as much biomass as possible for dairy animals. Maize (frequently silage) based rotations include oats, perennial rye grass, annual rye grass, Kikuyu, clover, canola, serradella and vetch, some as pure swards and others mixed. One of the most successful rotations utilised is kikuyu + clover (3-4 years) and silage maize (1 year). Kikuyu has a very well developed root system that helps improve the soil physical condition and increase the macro aggregates in the soil. Clover supplies nitrogen that is important to build up the soil organic matter and increase the N available to silage maize. The soil organic matter has a C/N ratio ranging from 10 to 13, thus the gramineae cover crops provide carbon while the legumes add nitrogen.</td>
<td>Amado 2003 in Fowler 2004</td>
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<td>Country</td>
<td>Area</td>
<td>Research topic and details</td>
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<td>Western Cape</td>
<td>South Western Cape (Swartland) and Southern Cape (Ruens). Swartland – Rooi Karoo, Moorreesburg, Eendekul, Suid Kaap – Heidelberg, Bredasdorp</td>
<td>Gross margin analysis comparisons between CV and NT in favour of the latter. Research also refer to adoption figures of Western Cape NT farmers</td>
<td>Roux 2003 Fowler 2004</td>
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<td>Elzenburg trials and research at Langgewens and Tygerhoek (4 longterm CA projects) Cover crop use (to enhance soil health) – including search for feasible cover crops and implementation strategies. MSc on carbon functional pools within CA at Tygerhoek – finished in 2013 J Smith Univ Stellenbosch MSc on functional carbon pools within CA in the Swartland underway (forthcoming)</td>
<td>Strauss et al. 2012 Hardy et al. 2011 CA/NT work under auspices of Conservation Agriculture Western Cape association</td>
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<td>ASSESSING THE IMPACT OF CONSERVATION AGRICULTURE PRACTICES ON WHEAT PRODUCTION It was concluded that the uptake of CA technology was significant in the province, and that apart from increasing profit margins, it also improves soil health, build soil structure, break up pest cycles, reduce soil erosion and improve water quality. It also found that the technology was not limited to specific field sizes or farmer profiles, confirming the versatility of the technology (ARC 2014).</td>
<td>ARC 2014</td>
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<td>Western Cape</td>
<td>Foundations for Farming active in western cape</td>
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<td>Northern cape</td>
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<td>KZN</td>
<td>Okhahlamba municipality (close to Winterton, Bergville)</td>
<td>Conservation agriculture practices an interesting option for the smallholder farmer communities of the Okhahlamba Local Municipality, KwaZulu Natal? The natural capital of the Okhahlamba Local Municipality (OLM) fulfils a crucial role in the provision of ecosystem services both at a local and global scale. However, the erosion and land degradation caused by several unsustainable land management practices is reducing both the quantity and quality of these services. Three land use categories are involved: conservation areas, commercial agriculture and communal land use. The communal land consists primarily Of vast grasslands used for grazing of the cattle, and cropping fields where small scale food production for household consumption takes place. The lack of sound management of the grasslands and the use of unsustainable cultivation practices on the fields is dramatically decreasing the agricultural potential of the region. Focusing on the cropping fields, this thesis highlighted the potential of conservation agriculture (CA) to control erosion and safeguard the land and water based ecosystem services of the region, provided that a broad scale adoption by the smallholders is realized. However, so far the adoption of CA among South African smallholders has been poor and often unsustained.</td>
<td>Elleboudt 2012 (University of Gent)</td>
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<td>Refer also to work of late Richard Fowler, Alan Manson, Mike Steinke and others</td>
<td>Russell and Gibbs 1995 in Fowler undated</td>
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<td>Cedara &amp; KZN area</td>
<td>ARC</td>
<td>Refer also to work of late Richard Fowler, Alan Manson, Mike Steinke and others</td>
<td>Russell and Gibbs 1995 in Fowler undated</td>
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<td>KZN</td>
<td>KZN No Till club</td>
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<td>Lesotho</td>
<td>Mohale’s Hoek district</td>
<td>Cover crop research (Maphutseng) Comparing carbon dioxide flux between No-till and conventional tillage (Maphutseng).</td>
<td>Eash et al. 2011 O-Dell et al. 2013</td>
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Appendix 3  Main results of national survey on organic produce

The following list was published by Barrow (2006) following analysis of a national survey. Since this date there are likely to have been some shifts:

Plant products:

- **Vegetables:** Organic salad and cooked vegetables are perhaps the most common form of organic production. The vegetables include different varieties of lettuce, cabbage, broccoli, cauliflower, butternut, squash, marrows, peas, beans, radish; in fact all of the “Western” salad vegetables as well as some “Eastern” vegetables. High value vegetables, such as asparagus, are typically exported to Europe.

- **Herbs:** A wide range of culinary, medicinal and aromatic (oil) herbs are grown. Again the list is extensive – one certified medicinal herb farm alone cultivates over 100 different herbs and medicinal plants. Cultivated indigenous plants are included in this category.

- **Grains and oil seeds:** Organic grains and oil seeds are less commonly grown. However, those grown include maize (certified non-GMO), soybeans (certified non-GMO), wheat, sunflowers, rye, triticale and oats. These may be consumed either by humans or livestock (for certified milk and egg production).

- **Deciduous fruit:** Mainly apples, most of which are exported to Europe.

- **Citrus fruit:** Oranges, lemons, clementines, most of which are exported to Europe. This is a significant export market.

- **Berries:** These include strawberries (for the domestic market), and blueberries (exported to Europe and for the domestic market), and raspberries.

- **Grapes:** Both red and white wines are made from certified grapes, and sold into both the domestic and export market. Some of these wines are made from Bio-Dynamically produced grapes and exported to Europe without reference to the cultivation method. Certified table grapes are produced and sold locally.

- **Vine fruit:** Passion fruit is available in the domestic market.

- **Sub-tropical fruit:** The export of certified avocados is another significant segment of the organic industry. Other sub-tropical fruit produced are guavas (for pulping and export mainly to the USA) and very recently (late 2005) certified bananas have appeared on the domestic market.

- **Stone fruit:** A group of farmers in one particular locality have achieved certification of their olives. Their products were first marketed in 2004.

- **Wild harvested crops:** The Rooibos industry forms a major segment of the certified organic producers in South Africa. However not all of the Rooibos is wild harvested, there being a significant amount that is cultivated. Honeybush, Buchu and rosehips are the three other major wild harvested crops. Some wild harvested medicinal herbs are also being certified, while others, such as Devil’s Claw, are no longer being certified.

- **Cultivated pastures:** The certified dairy industry is very small, and based on certified pastures. The certified poultry (for egg production) roam on cultivated pasture.
• Fodder: Certified fodder crops are usually grown by dairy and poultry farmers in order to achieve certification of those products.

Livestock products:

• Meat – beef: There were a number of certified farmers in 2002 through to 2004 but due to various difficulties, certified organic beef production is no longer a feature of the South African organic industry.

• Meat – poultry: As far as can be ascertained, there are no certified poultry meat producers in South Africa.

• Meat – sheep: The beef scenario has been mirrored in the sheep industry.

• Meat – goats: As far as can be ascertained, there are no certified goat meat producers in South Africa.

• Meat – pigs: As far as can be ascertained, there are no certified pork producers in South Africa.

• Dairy products: The certified dairy producers supplying milk to Woolworths are still in conversion. The number of these farmers has not been ascertained. Certified cheese, cream, and yoghurt are also available.

• Poultry – eggs: Only one certified egg producer is known to the surveyor.

Processed products:

• Herbs: Certified herbs are sold with or without reference to certification. Reference to certification of culinary herbs usually depends on the processor. At least one major processor purchases and retails certified herbs for the sake of quality and not for their organic status. Medicinal herbs are usually not processed into certified products either because of the limited volumes or the fact that the final products may not be certified based on the percentage of certified ingredients. A wide range of aromatic oils are grown for the extraction of certified oils.

• Deciduous fruit: Certified organic apple juice is available in the domestic market.

• Sub-tropical fruit: There is one certified guava puree producer known to the surveyor.

• Stone fruit: Olives are pickled, processed for their oil, made into products such as tapenade and jam, or salted and dried.

• Grapes: Both red and white wines are made from certified grapes.

• Wild harvested crops: Rooibos and Honeybush are fermented, dried, and packed as teas. These may be blended with each other, or herbs, such as lemongrass and comfrey. A limited amount of Buchu is also processed.

• Other crops: Cultivated indigenous crops such as Rooibos, Buchu, Pelargonium, and others.

Agricultural inputs:

The range of certified organic or non-organically produced products accepted as inputs into certified organic agriculture has grown remarkably. These include:
• “Composted” manures (the use of the term compost is a misnomer, as these manures are not necessarily composted with components such as green plant materials and clay, and usually consist of manure from non-factory farmed poultry and the litter, typically wood shavings). Some of these manures are pelletised.

• Bone-meal based fertilisers.

• Microbial products, as compost starters, soil conditioners and plant protection products.

• Plant oil based plant-protection products.

• Inputs, traditionally used in non-certified agriculture, such as mined minerals (mainly lime, gypsum and hard rock phosphate), sulphur and copper products have been available for many years.