AGRICULTURE AND THE CIRCULAR ECONOMY

Improved food security in South Africa through a more circular agricultural sector

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EXECUTIVE SUMMARY

Agriculture plays an important role in the South African economy, being deeply interconnected and central to many other industries and their operations. South Africa is a major producer and exporter of agricultural products, with the country consistently remaining a net exporter over the last decade. Agricultural exports amounted to USD10.2 billion in 2020 and a record USD12.4-billion in 2021, creating 829,000 jobs. However, the agricultural sector is resource intensive with a heavy reliance on water, energy, soil, nutrients and natural cycles, as primary inputs.

To feed a growing South African population will require embracing new farming methods that can help increase productivity, while reducing associated environmental impacts. While previous evolutions in farming have largely been driven by mechanical improvements (namely, bigger, better machinery), genetic advances (improved seeds), or green revolution (more effective fertilizers, etc.), the next big transformation is being driven by digital tools and lifestyle changes. A number of new, disruptive, technology trends are emerging in the agricultural sector and are regarded as key market opportunities, including the circular economy. The circular economy is based on the principals of designing waste and pollution out of the system, keeping products and materials in use, and regenerating natural systems. Implementation of these transformative technologies requires a collective approach from all stakeholders.

The objective of this study was to carry out an in-depth assessment on the circular economy in the food and agricultural sector in South Africa – from a resource perspective. The project was designed to inform public and private sector responses on where immediate circular economy opportunities are achievable. In addition, this project will also position the CSIR to undertake targeted research and development in future, based on where significant opportunities are evident for the country. By identifying where resource constraints may severely constrain future socio-economic development, the CSIR can focus internal research activities to address these issues of national importance.

The study focussed on two research questions – (1) the current agricultural sectors development path, which included an overview of current resources within the sector (availability and demand); expected trends in the sector (with little to no major disruption); an analysis of potential resource constraints for future growth of the sector, and (2) a possible circular development path for the agricultural sector, which included identifying innovative circular economy interventions; assessing the appropriateness of these interventions for South Africa; critically assessing the readiness to implement these circular economy solutions; assessing the business opportunities to implement these circular economy solutions; and finally providing an indication of the greenhouse gas (GHG) mitigation potential of the various circular economy interventions.

The methodology employed included an initial desktop study aimed at understanding the relevance of the circular economy to the South African agricultural sector. This was followed by a more in-depth study which involved collating secondary data through a literature review, gathering primary data through stakeholder engagements, survey questionnaires, and stakeholder workshops/focus group discussions.

The main findings showed that stakeholders are aware of most of the circular economy interventions applicable to the agricultural sector. However, a few stakeholders were uncertain with regards to the less familiar interventions, such as chemical leasing, zero tillage, equipment sharing, vertical farming and precision agriculture. The South African agriculture sector is ready, and has already implemented, some circular economy interventions although at various scales.

There are a few interventions that will take longer to implement as a result of certain challenges facing the sector. Financing appeared to be the most persistent barrier, including the high upfront investment costs for some interventions. Enterprises are mostly profit-oriented, however, for the sector to become sustainable, entrepreneurs and companies should be able to access conventional financing with preferential rates. The second highest rated challenge was the need for pilot and demonstration facilities to showcase circular interventions to e.g., farmers and policy-makers. There is a need for policies that will favour growth of the sector through sustainable and circular interventions. Awareness creation, and the availability of the right technologies were also some of the barriers in scaling.

Business opportunities identified ranged from food waste interventions, regenerative agriculture, to precision agriculture, agro-processing, sustainable packaging to extend product life, and urban farming.

Finally, stakeholders identified climate change as a severe challenge facing the South African agricultural sector. Agriculture also has major impacts on the environment, being a leading contributor to GHG emissions, water consumption, nitrate and ammonia pollution. Mitigations proposed were generally towards regenerative agriculture interventions (crop rotation, minimum tillage, green manure, integrated pest management) that can reduce GHGs.

CONTENTS

ACRONYMS

CE	Circular Economy
CSA	Climate-smart agriculture
DALRRD	Department of Agriculture, Land Reforms and Rural Development
DFFE	Department of Forestry, Fisheries and Environment
DSBD	Department of small Business Development
DSI	Department of Science and Innovation
dtic	Department of Trade, Industries and Competition
EC	European Commission
EU	European Union
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GVA	Gross value-added
HCD	Human Capital Development
ILO	International Labour Organisation
IPM	Integrated Pest Management
NCP	National Curriculum Vocational
OECD	Organisation for Economic Co-operation and Development (
RDI	Research, Development and Innovation
SSEG	Small-scale embedded generation
SPIS	Solar-powered irrigation systems
UNDP	United Nations Development Program

1 Introduction

1.1 Background

Agriculture plays an important role in South Africa's economy, especially when considering the sector is deeply interconnected and central to many other industries and their operations (Quantec, 2020). The sector relies heavily on resources and natural cycles as its primary inputs. Resources such as water, energy, soil, and nutrients underpin the functioning of the ecosystem in which the sector operates. However, these resources are finite and are already facing constraints. Growing food demand has resulted in environmental impacts such as deforestation, biodiversity loss, land degradation, eutrophication, and greenhouse gas emissions, impacting negatively on food security. The sector also currently faces numerous challenges, such as climate change which is directly affecting agricultural productivity in South Africa through changes in precipitation, temperature patterns, surface water runoff, and new pests and diseases (Johnson, 2020).

Modern agricultural practices, such as monocropping, which has replaced traditional methods of growing multiple crops on a piece of land, has resulted in soil productivity losses and soil degradation. This is aggravated by the increased use of chemical fertilizers and synthetic pesticides facilitating a vicious cycle whereby with each harvest, more pesticide and fertilizer inputs are required. South Africa already faces declining soil quality and generally, low soil organic matter levels (Du Preez, 2011). Soil organic matter is important for the sustainability of agricultural soils.

Our food systems and consumption practices are major contributors to the triple planetary crisis of climate change, nature and biodiversity loss, and pollution and waste. Food losses and waste account for up to 10% of greenhouse gas (GHG) emissions. Globally, 931 million tons of food waste was generated in 2019, 61% from households, 26% food service and 13% from retail equivalent to 17% global production. Households generate an average 74kg per person per year, more than the body weight of an average person (UNEP, 2021). In South Africa, the situation is no different. Food losses and waste are a growing reality, estimated to be in the order of 10.3 million tons in 2021, or 34.3% of local production. In 2013, the cost of food losses and waste to society was already R61.5 billion, equivalent to 2.1% of South Africa's GDP (Oelofse *et al.*, 2021).

Continuing to follow a resource intensive, linear growth path, focused on short-term efficiency gains, will ultimately risk national food security. On the other hand, a systemic approach based on circular economy principles can build a value-preserving model that would be regenerative, resilient, non-wasteful and healthier (EMF, 2016). When applied to the agricultural sector, the circular economy principles of designing out waste and pollution; keeping products and materials in use; and regenerating natural systems, provide a framework for South Africa to address food security.

Circular agriculture as depicted in Figure 1 below centers on a regenerative system, with the production of agricultural commodities using a minimal amount of external inputs; decoupling production and processing from resource utilization; closing nutrient loops; restoring soil fertility; and reducing discharges to the environment.

Figure 1. Circular agriculture and the valorization of unavoidable waste from the agri-food sector (adapted from Scholten, 2021 and AgrocCycle, 2021).

Circular agriculture means that we keep residuals of agricultural biomass and food processing within the food system as renewable resources. If done properly, circular agriculture therefore, has the potential to make businesses more economically viable, competitive, and sustainable in the long-term, reducing risks linked to external inputs and commodity prices; reducing the pressure on natural resources; and opening new revenue streams through innovation, new technologies and collaboration between sectors and industry. Secondly, when scaled, circular agriculture can reduce resource requirements, GHG emissions, land use, water and energy, chemical fertilizers, synthetic pesticides and ultimately the ecological footprint of agriculture thus reducing production cost. A transition to a circular economy, requires a strong evidence base to understand the opportunities that this transition will yield for increased industrialisation.

1.2 Objectives

The objectives of this study were to explore the circular economy opportunities in South Africa's agricultural sector.

The following research questions were addressed:

1) What is the current development path for the South African agricultural sector?
2) What could a circular development path for the South African agricultural sector look like?

1.3 Methodology

The methodology employed to answer the above research questions, included an initial desktop study aimed at understanding the relevance of the circular economy to the agricultural sector. This culminated in the publication of a short, introductory briefing note titled "*Supporting food security and economic development through circular agriculture*" (Okole *et al*., 2021). The initial concepts of the research that were documented in the briefing note were presented at the CSIR Circular Economy project launch held in November 2021 and published by the CSIR in a book titled "*The circular economy as development opportunity*" (Godfrey, 2021).

This was followed by a more in-depth study which involved collating secondary data through a comprehensive literature review of the agricultural sector. The literature review was followed by primary data collection through stakeholder engagement which included the distribution of an online structured questionnaire, one-on-one virtual meetings, and a stakeholder workshop held on the 22 February 2022. The feedback from these sessions greatly helped to enrich the study and provided a more inclusive response to the circular economy opportunities in the South African agricultural sector. Over 40 respondents participated in the workshop and the one-on-one virtual meetings.

Research questions on the current development path involved a brief overview of the sector (including economic relevance of sector); overview of current resources within the sector (availability and demand); expected trends in the sector (with little to no major disruption); an analysis of potential resource constraints for future growth of the sector (based on above findings and identification of key economic and socio-economic gains and losses associated with current path).

Research questions for the circular development path involved identifying innovative circular economy interventions; assessing the appropriateness of these interventions for South Africa; critically assessing the readiness (including potential obstacles and unintended consequences) to implement these circular economy solutions; assessing the business opportunities to implement these circular economy solutions (including possible high-impact circular economy projects in the sector); analyzing how these circular economy interventions could address resource constraints, while unlocking environmental, social and economic opportunities, and finally providing an indication of the GHG mitigation potential of the various circular economy interventions. This approach allowed the project team to answer the above research questions for the agricultural sector.

2 Current development path for the South African agricultural sector

2.1 Overview of the sector

South Africa's agricultural sector is diversified, and is a major producer and exporter of agricultural products. South Africa has consistently remained a net exporter over the last decade, with agricultural exports amounting to USD10.2 billion in 2020 (Figure 2) (Sihlobo, 2021).

The wide variety of agricultural commodities are driven by large-scale commercial farmers using sophisticated systems, and small-scale family farms that practice small-scale farming. Food production and retail is dominated by large corporations and supermarket chains (Oelofse *et al*., 2018). Unlike many other African countries where small-scale farmers dominate, there are approximately 32,000 commercial farmers in South Africa, of which between 5,000-7,000 produce approximately 80% of the countries agricultural output (US International trade and Administration, 2022).

South Africa's agricultural sector has had two consecutive years of solid growth, with its gross value-added (GVA) expanding by 13.4% year-on-year in 2020 and 8.3% year-on-year in 2021. This was a period of favourable rainfall, which supported crop yields and grazing conditions for the livestock sub-sector; weak exchange rates; and high demand especially in the maize, eggs, and citrus sub-industries (BFAP, 2021). In addition, the higher commodity prices, specifically for grains and oilseeds, also boosted farmers' incomes in 2020 and 2021. The increased global demand for agricultural commodities during this period saw South Africa exporting USD10.2 billion of agricultural products in 2020 and a record USD12.4-billion in 2021 (Sihlobo, 2022).

Sihlobo (2021) further reported that the allied industries, such as agricultural machinery, benefited from improved farmers' incomes throughout 2020-21. During this period, these positive agricultural production conditions were also mirrored in employment rates in the sector, with 829,000 people involved in primary agriculture in the third quarter of 2021, up by 3% year-on-year, and well above the long-term agricultural employment of 780,000.

Agriculture plays a crucial role in food security, supplying the basic products that keep millions of people fed every day. Statistics South Africa's recently released Agriculture Survey (2019), provides an overview of the most popular products and goods in the agriculture and related services industry, according to sales data (Figure 3). The largest sales were from animals and animal by-products (R153.1 billion), followed by horticultural crops and products (R86.3 billion), and field crops (R61.9 billion).

Within the next decade, the ability of the South African agricultural sector to produce an adequate supply of food for the growing population, without creating excessive negative environmental impacts, will be tested. Risks to the South African agricultural sector range from climate change (unpredictable rainfall, diseases, and pest outbreaks); urban migration; land degradation resulting in the high usage of chemical fertilizers; high input costs; monocropping; water scarcity; high costs and unreliable energy supplies; and biodiversity loss. In addition, geopolitics and wars create further risks to the agricultural sector and resultant food security, through low supplies, for example fertilizers, and high prices (CSIS, 2022). These and many more that will be highlighted in this report, are putting increasing pressure on South Africa's agricultural sector.

None of these issues has gone unnoticed and the government has signalled its intentions to increase agricultural productivity and reduce food losses so that South Africa can maintain a high degree of food security (SA Government, 2022).

Figure 2. South Africa's agricultural trade (2010-2020) (Sihlobo, 2021)

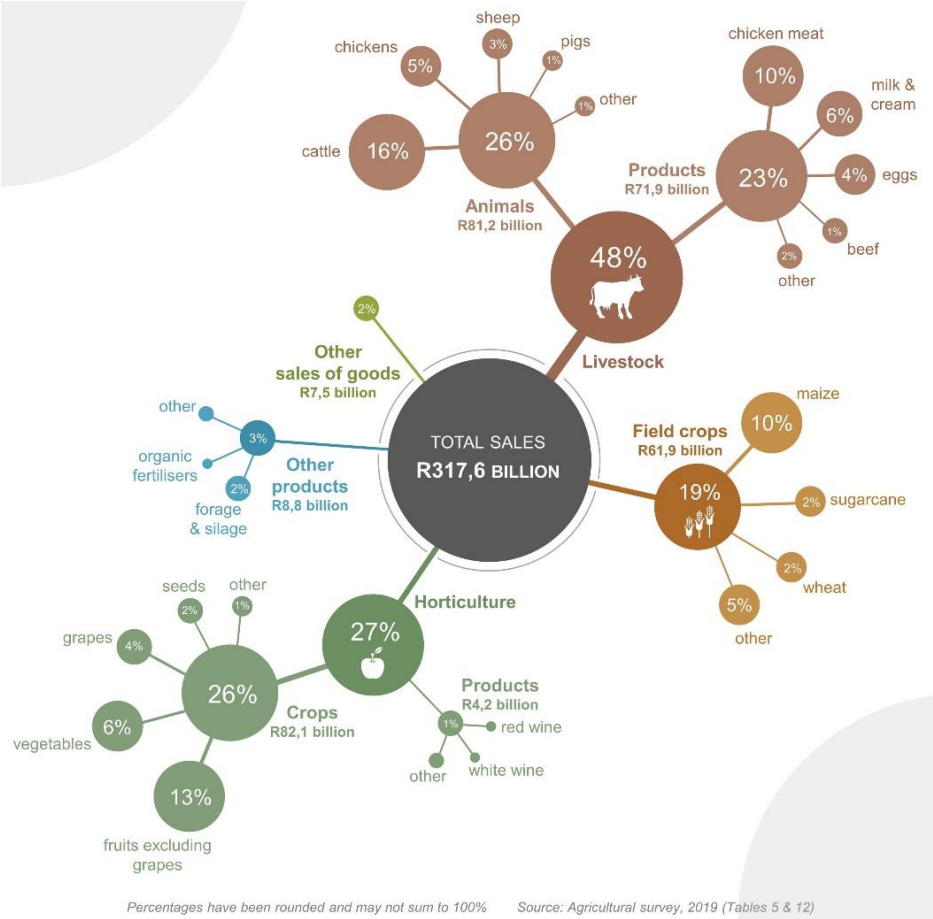


Figure 3. The goods that drive South African agriculture (sales of goods in agriculture and related services) (StatsSA, 2021)

2.2 Current resource use within the sector

The agricultural sector is resource intensive and relies on resources such as water, energy, soil, nutrients, and natural cycles, as primary inputs (Okole *et al.,* 2021).

2.2.1 Water availability and demand

South Africa is regarded as water-scarce, with an average annual rainfall of about 460 mm or less. The country uses 98% of available water supply, most of which comes from surface water (68%) and return flows (used and recycled water) supporting surface water (13%) GreenCape, (2021). The demand for water is expected to exceed supply by 17% (or a 2.7–3.8 billion m^3 water deficit) by 2030 (World Bank Group, 2022). This gap is critical, and if sustainable socio-economic growth is to be envisioned, such a gap must be dealt with decisively in the coming decade.

About 61% of the country's water allocation is used for agriculture (Figure 4) with large irrigation schemes supplied from storage dams. Generally, agriculture in South Africa is rainfed, accounting for most of the harvested area (Hardy *et al.,* 2011). An estimated 10% of South Africa's cultivated land area is irrigated and it contributes to over 30% of gross value of the country's crop production (FAO, 2020). However, a large proportion of this water is lost during conveyance, and therefore does not reach farmers.

In addition to the high levels of water loss experienced during production, (e.g., irrigation losses), further water losses occur as a result of high levels of food waste. According to Oelofse (2014), the estimated water loss because of food waste (excluding fish and seafood) in South Africa was 12,854 Mm^3 – a water footprint of ~1288 m^3/t, or 22% of the total water footprint of agricultural production in South Africa. Cereals, meat, fruit and vegetables being responsible for ~82% of the water losses associated with food wastage in South Africa (Oelofse, 2014).

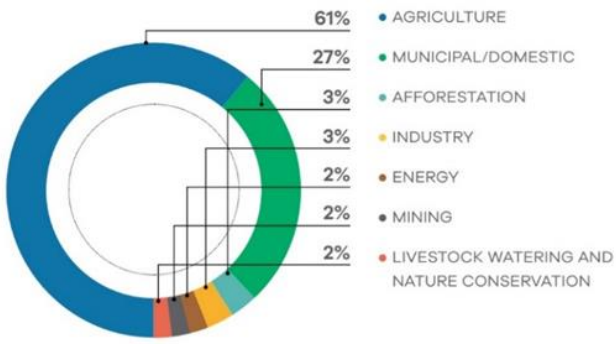


Figure 4. Water use allocated to the different sectors (GreenCape, 2021).

The demand for irrigated water is very high on certain crops, with 90% of the fruit and wine production (export commodities) and 90% of vegetable production (essential for national food security) depends on irrigation. Water demands are increasing, and water quality is deteriorating. This will impact negatively on the country's economic development. The use of treated wastewater, rainwater harvesting and return-flow systems where drainage and surplus irrigation are channeled back to the network are integral agricultural elements of circular agriculture.

2.2.2 Energy availability and demand

Energy drives agricultural activities, with agriculture accounting for 6% of South Africa's energy demand in 2019 (Figure 5) (DoE, 2019).

The agricultural sector has a high demand for liquid fuels, accounting for 68% of its energy demand, followed by electricity at 31% and finally coal at 1% as shown in Figure 6 (DOE, 2019). Energy needs are mostly for farming machinery, and transportation of raw materials, feeds, intermediary and finished products from farms to markets. South Africa's energy is generated mainly by fossil fuels, which accounts for 95% of primary energy consumption. South Africa, like many other countries, is struggling to ensure energy security, essential to sustain and grow all economic sectors. In the agricultural sector, continued or increased energy constraints could lead to disruptions in farming operations, production output, and eventually getting products to market. A few commercial farms have started looking into alternate energy such as biofuels, wind energy in coastal areas, and solar energy to ensure energy security.

2.2.3 Land availability and demand

Land used (as opposed to farm size), for commercial agriculture is 46.4 million hectares, which represents 37.9% of the total land area of South Africa. Commercial agricultural land is comprised mainly of grazing land (36.5 million hectares) and arable land (7.6 million hectares). There are approximately two million smallholder or household farmers (with farm sizes ranging from 0.5ha to 5 ha) compared to 32,000 commercial growers (over 50 hectares). Many of these small-scale farmers are in rural areas, remote from big markets and rely predominately on the land to feed their families, with hopefully some surplus to sell or trade. Grazing land is used for livestock and game farming, and arable land is used for crop production. The Northern Cape province accounted for the largest share of the country's commercial agricultural land (37.1%), followed by the Free State (16.4%), Eastern Cape (12.3%), North West (11.5%), Limpopo (3.7%) and Gauteng (0.8%) (StatsSA, 2020). Potential constraints on land available for agriculture could reduce agricultural output, contribution to GDP and lead to job losses in the sector.

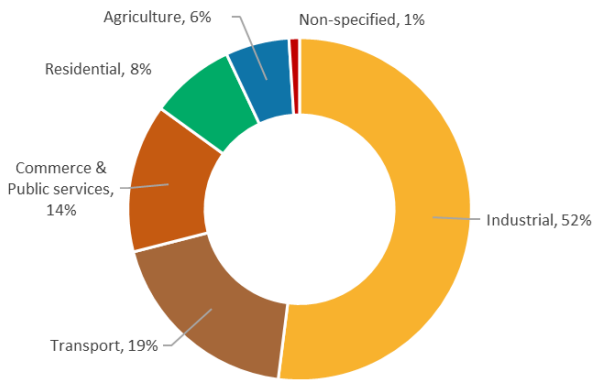


Figure 5. Energy demand per sector (DoE, 2019)

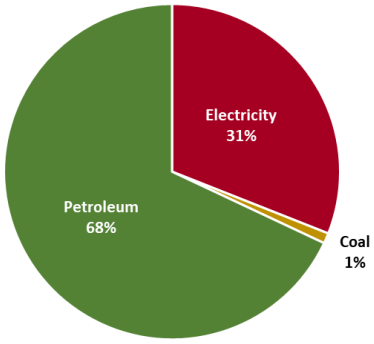


Figure 6. Energy type demand by the agricultural sector (DOE, 2019)

2.2.4 Soil degradation

In South Africa, land degradation is a significant issue where nearly 60% of the land is already degraded (UNEP, 1997) and 91% prone to desertification (Hoffman and Ashwell, 2001). Although soil degradation is a natural process, it is often accelerated by human activities like deforestation, firewood collection from the wild, soil tillage, poor farming practices, overgrazing and the erratic changes in weather and climate conditions. Soil degradation normally leads to depletion of soil fertility. A decline in soil fertility or quality results in lower crop productivity, prompting farmers to make greater use of expensive inorganic fertilizers, and in so doing reduce their profits. Reversing land degradation would lead to economic gains. Regenerating natural systems using simple circular economy indigenous knowledge systems like mixed cropping, rotational cropping, rotational grazing, zero tillage, etc. can lead to:

- Improved soil health by replenishing organic soil matter and improving the biome (the bacteria and fungi that provide food for invertebrates and microscopic organisms).
- Increased carbon capture of the soil by storing it underground (the microorganisms that enrich the soil are made of carbon, and carbon is captured by maintenance of crop and root systems).
- Increased biodiversity by supporting beneficial insects, pollinators, songbirds, and other wildlife that improve farm biodiversity and resilience.

2.2.5 Fertilisers availability and demand

South Africa's fertilizer industry is experiencing a bumper year on the back of rising fertilizer prices and record maize production, which accounts for more than half of all fertilizer consumed in the country. However, there is concern over increasing imports and a decrease in local production (Business Wire, 2021). In 2018, chemical fertilizer consumption for South Africa was 72.8 kg/hectare compared to a sub-Saharan average of 17 kg/hectare (Knoema, 2018). South Africa's chemical fertilizer consumption is more than three times higher than the sub-Saharan average (Knoema, 2018). Nitrogen- and phosphorus-based fertilizers are known to be heavy pollutants when they run-off farmlands. This creates an opportunity to switch to the use of organic fertilisers, so that nutrient loops are closed and the need for inorganic fertilisers is reduced. The application of organic fertilisers will also help to rebuild the topsoil and soil holding capacity of agricultural lands.

For centuries, farm, food and animal waste from livestock farming has been used as a source of fertilisers and soil improvers for agriculture. Rich in macro-nutrients like nitrogen, phosphorus and potassium, they enrich the soil and improve its aesthetics. When optimally implemented, these pathways can result in full value chain processing of waste biomass and obviates the need to dispose of waste through landfilling, burning, stockpiling, or discharge to sea, thus mitigating the generation of GHG emissions.

2.2.6 Pesticide's availability and demand

The use of pesticides has changed agriculture dramatically. Pesticides have significantly increased yields and improved quality in most cultivated crops. But the widespread use of pesticides has also caused harm to human health and the environment, including impacts on water, climate and biodiversity (PAN 2022). The agriculture sector applies 4.6 million tonnes of pesticides. The global pesticide industry is worth more than USD 35 billion per year (Mateo-Sagasta *et al*., 2018).

South Africa has more than 500 registered pesticides (PAN, 2010) because of its intensive farming and is one of the four largest importers of pesticides in sub-Saharan Africa (Osbanjo *et al*., 2002). These pesticides must be applied to maintain high yield and bumper harvest. Unfortunately, the use of pesticides comes at a cost if irresponsibly applied or disposed. The hazards associated with pesticide use are real. With the strong lobbying power of environmental groups, pesticides are now viewed as a sensitive issue. The European Union is taking the lead in banning carcinogenic (cancer-causing), reprotoxic (interfering with human reproduction) and mutagenic (capable of inducing heritable genetic defects) pesticides. Alternate methods to control pests and diseases include Integrated Pest Management (IPM). IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of practices where pesticides are used as the last resort to control pests. IPM protects humans and the environment from negative effects from pesticides. IPM is also a way for farmers to deal with "pesticide resistance". There are also low toxic biological control agents that are now popularly used especially by fresh vegetable farmers to control pests and diseases.

Other potential resource constraints include climate variability, lack of appropriate agricultural infrastructure and equipment, shortage of farming skills, poor market information and poor logistics to markets to name a few.

2.3 Expected trends in the sector

To feed the growing global population, estimates suggest food production will have to be increased by as much as 68% by 2050 (Marr 2022). Embracing new farming methods could help the agriculture industry reduce its environmental impact while still increasing productivity. While previous evolutions in farming have largely been driven by mechanical improvements (namely, bigger, better machinery), genetic advances (improved seeds), or green revolution (more effective fertilizers, etc.), the next big transformation is being driven by digital tools, lifestyle changes and recent pandemics, that are making us think differently.

2.3.1 COVID-19

The Covid-19 pandemic has exposed the fragility of relying on a linear food system, underscoring the urgent need for systemic and enduring change. The pandemic has increased global food insecurity in almost every nation. The forced reduction in production because of a national lockdown in South Africa; the impact of the lockdown on household demands for goods and services; the effect of disrupted global production and supply chains on South African exports / imports; and the effect of uncertainty on business investment; is forcing the South African food and agricultural sector to think differently. Mtulu and de Lange (2021) reported that 2020 and 2021 have been exceptionally challenging years around the globe. The COVID-19 pandemic has, along with climate change and political turmoil, changed consumer preferences and put the South African agricultural sector under much strain. Fortunately, despite the pandemic, agriculture performed well in 2020-2021 amidst various lock-down restrictions imposed to curb the spread of the Covid-19 virus. The sector is expected to be a key driver of a post Covid-19 economic recovery, both locally and internationally. Investments made in improved and sustainable food production, collection and distribution can enable greater food security and ensure higher profits across the value chain for businesses.

2.3.2 Urban regenerative farming and local value chains

With estimates suggesting that 80% of food will be consumed in cities by 2050, cities can significantly influence the way food is grown, particularly by interacting with producers in their peri-urban and rural surroundings. Urban agriculture makes it possible to produce fresh, nutritious food with low carbon and water footprints, while conserving land, reducing emissions and waste, and providing healthy, affordable, accessible food to all. Regenerative approaches to food production will ensure the food that enters cities is cultivated in a way that enhances rather than degrades the environment, as well as creating many other systemic benefits. In parallel, cities can use circular urban farming systems. Urban farming remains in its infancy in South Africa, but growing interest in sourcing food locally is spurring growth. Urban farming may not replace hinterland agriculture, but it well complements the food system facing the increasing pressures of demographic growth coupled with land scarcity.

New technologies are helping to make urban farming increasingly viable and a potential actor in food systems. Many urban farming initiatives are taking place in abandoned industrial lands, often making use of former warehouses to create a controlled environment to allow for year-round production. Urban farming has multiple advantages: by using less land, less water and energy, it reduces the need to clear forests to make way for cultivation land. Urban regenerative farming includes undercover farming which ranges from low-tech infrastructure such as shade netting to higher-tech controlled environment glass house systems, vertical farming, hydroponics (growing plants in nutrient-rich water), and aquaponics (raising aquatic animals such as fish, crayfish, snails or prawns in tanks).

2.3.3 Food technology companies and change in consumer preferences

The South African class group is very dynamic. More people are entering the middle class than at any time in history; a trend that is expected to continue over the coming decade. The issue here is that entering the middle class typically correlates to a significant increase in animal protein consumption, which is very resource intensive. Consumers today are more educated about food than ever before, this can be seen from eating habits with new kinds of food products with specific labels, ready to eat foods, and organic or plant-based foods. Applying innovative food technologies to the creation and production of new food products, new alternative proteins, new dairy products, or even the ingredients or flavours that have to get into those end products are an emerging trend in the sector.

2.3.4 Organic fertilizers

An opportunity exists to increase the use of organic fertilisers in the South African agricultural sector, so that nutrient loops are closed and the need for mineral fertilisers is reduced. There is also a need to rebuild the topsoil and soil holding capacity of agricultural lands. South Africa is developing a keen interest in using biochar (pyrolyzed biomass) as a soil amendment and compost from plant/food waste due to its potential to:

- Permanently sequester carbon in soils (slow to degrade compared to compost or manure)
- Improve the fertility of degraded soils
- Potential to co-generate electricity

Sources of biomass used include e.g., alien invasives and agro-industrial wastes (Potgieter *et al*., 2020).

2.3.5 Hemp production

The 2018 Constitutional Court judgment made it legal for farmers to produce and sell all forms of hemp. In 2021, the crop was classified as an agricultural crop. The plant can be used to create over 130 items from the flower to leaves, stems and roots. The hemp market is one that is poised to see enormous growth in the South African agricultural sector. The fibre from these plants can still be processed for other industrial uses. The hemp plant can be used to clean up old mine dumps making it fit for agricultural production.

2.3.6 Technology trends

A number of new, disruptive, technology trends are emerging in the agricultural sector and are regarded as key market opportunities. These include:

- *Precision farming* involves irrigating, or applying fertilizers and pesticides at variable rates, depending on the needs of crops, rather than uniformly applying them at set times, quantities, and frequencies, potentially reducing resource consumption (Marr 2022). It is a technology that is now being practiced in the agricultural sector by big commercial farmers in South Africa. This technology can also be used in predicting yields, a game changer in the sector.
- *Climate-smart agriculture* (CSA) is an emerging opportunity that minimizes resource needs, builds resilience, and minimizes emissions by redesigning how we produce. CSA includes a range of practices such as conservation agriculture, livestock management and the use of soil-less systems. Soil-less systems such as hydroponics, aeroponics and aquaponics are gaining popularity in urban and peri-urban locations where land is scarce.
- *Mobile or digital platforms* that create better connections between producers and consumers to get the best prices for the rural farmers.

- *Renewable energy applications* on farms include small-scale embedded generation (SSEG), solar-powered irrigation systems (SPIS), distributed generation, storage and biogas (GreenCape, 2021).

- In the fertilizer domain, technology has been developed to produce *green ammonia* to solve one of the biggest pollution problems in the fertilizer sector. Green ammonia production is where the process of making ammonia is 100% renewable and carbon-free. One way of making green ammonia is by using hydrogen from water electrolysis and nitrogen separated from the air. Green ammonia for fertilizer, fuel, and heat could drive down farming's carbon footprint by as much as 90% for corn and small grain crops.

- *Agricultural drones* are becoming very popular in the South African agricultural sector. The drones are easy to fly and there are experts in the country who supply, understand and interpret the algorithms and data. Technology has improved to the level that drones can respond well even in the event of changing weather conditions, making it possible for farmers to have more detailed predictions about the state of the local weather in their area. This helps them determine what should be planted in any given timeframe as well as if crops should be harvested if weather conditions are about to change in their area.

- *Chemical leasing* which is centered around a unit of payment which is no longer related to the chemical itself, but to the benefits of the chemical. The focus shifts from increasing the sales volume of chemicals to a value-added approach.

- Digitally enabled *business models* to facilitate equipment / machine sharing or on-demand services.

- *Smart packaging* technologies and agro-processing technologies to reduce post-harvest and food losses.

- *Automation*, including the use of robots and autonomous tractors to make farming more efficient.

- *Alternative waste treatment technologies* such as anaerobic digestion or pyrolysis for producing organic compost from various biomass waste streams.

2.4 Losses associated with current path

The current path of agricultural production is linear and not good for our environment. The potential decreases in the availability of water and energy in the agricultural sector could lead to further reductions in the land areas under cultivation, production output, contribution to GDP and food security. In addition, the continued and increased use of chemical fertilizers and synthetic pesticides could lead to further soil productivity losses, declining soil quality and low organic matter levels. If the poor infrastructure and logistics for small-scale and household farmers are not improved, they will not be able to gain access to sufficient markets or improve their economic prospects.

2.5 Summary

Agriculture plays an important role in the South African economy, with the sector deeply interconnected and central to many other industries and their operations. South Africa is a major producer and exporter of agricultural products, and the country has consistently remained a net exporter over the last decade, with agricultural exports amounting to USD10.2 billion in 2020 and a record USD12.4-billion in 2021. This has also translated to an increase in employment from 780,000 jobs to a record 829,000 in 2021. Despite the good news, the sector is still facing numerous challenges. Some of which include climate change that is directly affecting agricultural productivity because of changes in precipitation, temperature patterns, surface water runoff, new pests, and diseases. Changes in agricultural practices, such as monocropping and overgrazing have resulted in soil productivity losses and degradation.

There is an opportunity to embrace circular economy principles to create a more resilient agricultural sector. A sector which is facing mounting pressures due to climate-related impacts, with knock-on effects impacting economic growth and transformation. The current development path will not be sustainable, to feed the growing South African population. Embracing new farming methods could help the agriculture sector reduce its environmental impact while still increasing productivity. Transitioning to circular agricultural practices aimed at designing out waste and pollution, keeping materials in use, and regenerating natural systems, provides numerous social, economic and environmental advantages, including jobs opportunities, and material and cost savings.

A number of new, disruptive, technology trends that are emerging in the agricultural sector and are regarded as key market opportunities have been highlighted in this section. Implementation of these transformative technologies must undergo a thought through process. Transformation will involve the commitment of all stakeholders, at all stages of the value chain, to ensure that these technologies are scaled up and create economic growth and positive impact for the sector.

3 Circular economy development path for the agricultural sector

3.1 Circular economy interventions

In the current context of resource scarcity, global climate change, environmental degradation, and increasing food demand, the circular economy represents a promising strategy for supporting sustainable, restorative, and regenerative agriculture.

Based on the assessment of the current status of the South African agricultural sector and the main pressures facing the sector, together with a review of expected trends in the sector, including local and international circular economy practices, a number of circular economy interventions were identified. These interventions may have potential for the local agricultural sector (Table 1).

The proposed circular economy interventions presented in the following sections were based on the desire to produce agricultural commodities using a minimal amount of external inputs; decouple production and processing from resource utilisation; close nutrient loops; restore soil fertility; reduce discharges to the environment; and drive greater food security.

3.1.1 Stakeholder engagement

The circular economy interventions applicable to the agricultural sector were tested with key stakeholders via an online questionnaire, one-on-one meetings and a stakeholder workshop.

When asked to what extent stakeholders agree that these circular economy interventions can benefit the South African agriculture and food sector, the results showed a high level of agreement for most of the interventions, with an emphasis on the more commonly practiced interventions. These included precision agriculture, agro-processing, composting, and packaging technologies (Figure 7). Reducing food losses and waste, and insect protein, were also raised by a number of stakeholders as additional circular interventions to consider. There was some level of uncertainly with regards to the less familiar interventions, such as chemical leasing, zero tillage, equipment sharing and vertical farming (Figure 7). The stakeholders confirmed the need to better understand the opportunities provided by some of these interventions, together with increased education and awareness as to the benefits they provide the agricultural sector.

Table 1. Proposed circular economy interventions for the agricultural sector

CE Intervention	Description & Benefits
Agro-processing	Agro-processing involves the transformation of primary agricultural products into value added products. This could be food products, nutraceuticals, cosmetics or African traditional medicines.
Aquaponics/ Aquaculture	Coupling aquaculture with hydroponics, whereby nutrient-rich aquaculture water is fed to hydroponically-grown plants
Biogas / Anaerobic digestion	Biogas is a mixture of gases, primarily consisting of methane, carbon dioxide and hydrogen sulphide, produced from raw materials such as agricultural waste, manure, organic fraction municipal waste, etc.
Chemical leasing	Chemical Leasing is a performance-based business model for sustainable chemicals management. Less chemical same effect.
Composting	Composting is the natural process of recycling organic matter, such as leaves and food waste, into a valuable fertilizer that can be used to improve the soil and feed the plants.
Crop Rotation	Crop rotation is the practice of planting different crops sequentially on the same plot of land to improve soil health, optimize nutrients in the soil, and combat pest and weed pressure.
Digital platforms	A Digital Platform allows your organisation to accelerate its time to market, increase revenue, reduce costs, and create innovative products for your customers.
Equipment sharing	Sharing of underutilised agricultural equipment to improve equipment productivity
Mixed farming	Mixed farming involves growing a set of interdependent crops and animal where the cultivation of one creates favourable conditions for others on the same land.
Packaging technology	Purposeful packaging, made of materials that can be repurposed, recycled, or biodegraded to increase the shelf life of food products.
Precision agriculture	Precision agriculture (PA) is an approach to farm management that uses information technology to ensure that crops and soil receive exactly what they need for optimum health and productivity. The goal of PA is to ensure profitability, sustainability and protection of the environment.
Urban farming	Urban farming is the practice of cultivating, processing, and distributing food in or around urban areas. This includes aquaculture, aquaponics, greenhouse growing etc.
Vertical farming	Vertical farming is the agricultural practice in which crops are grown in controlled environmental greenhouses on top of each other to minimise space, save water, energy and fertilizer use.
Zero tillage	Zero tillage is conservation agriculture where no tillage is applied between harvest and sowing. Zero tillage is a minimum tillage practice in which the crop is sown directly into soil without any land preparation

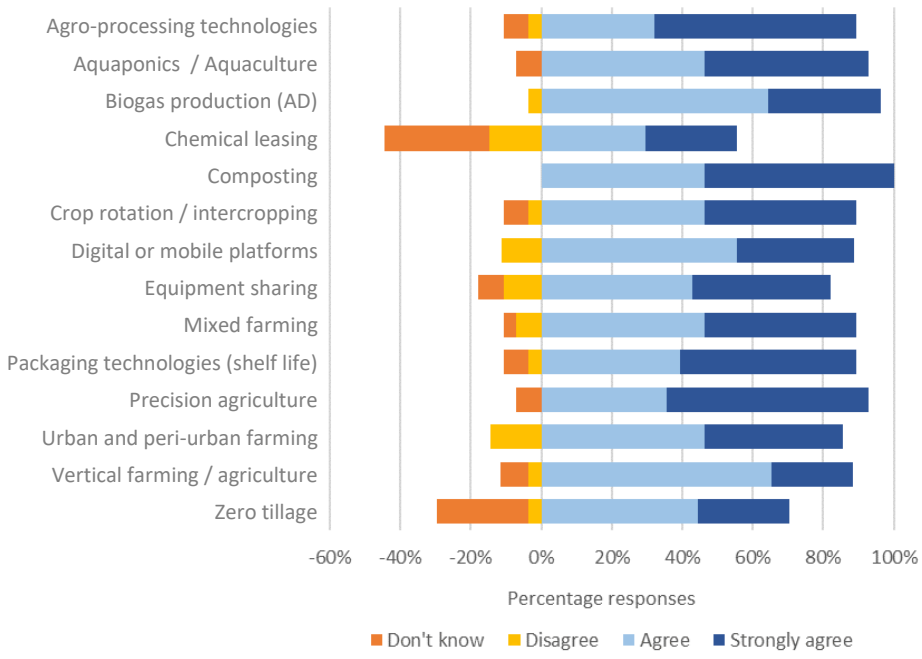


Figure 7. Extent to which circular economy interventions can benefit the SA agriculture & food sector

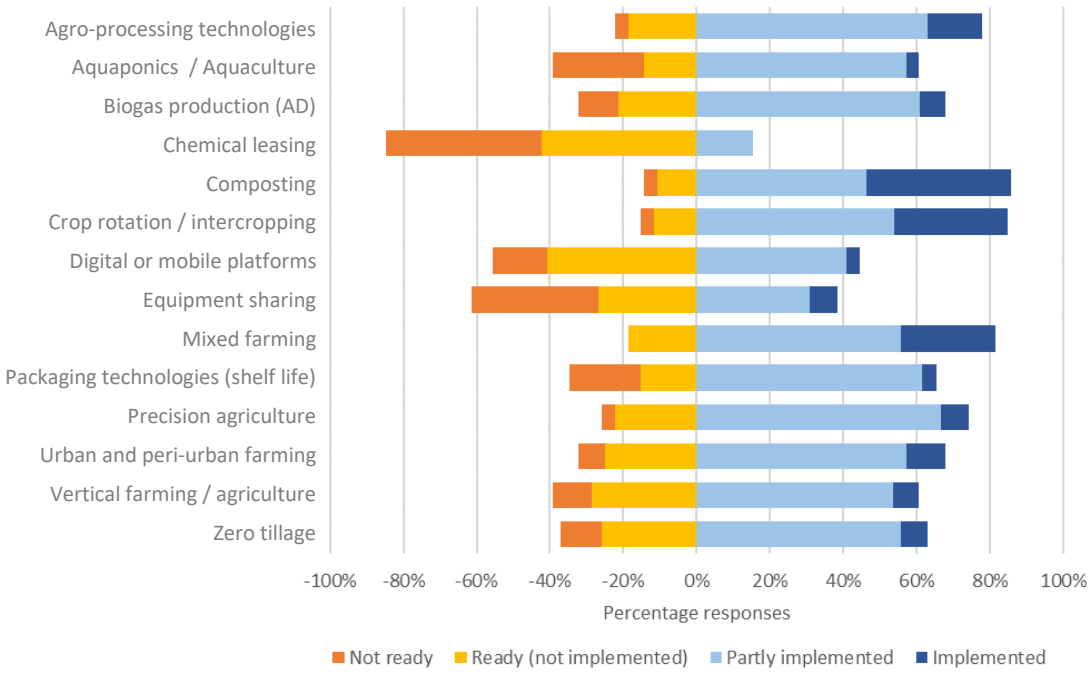


Figure 8. State of readiness and level of implementation of circular economy interventions in South Africa

3.2 Readiness to implement interventions

Many of the circular economy interventions listed here have strong application in the global north but are yet to find scale in South Africa. A key issue in determining the circular economy development path for the South African agricultural sector is to understand the appropriateness of these interventions and their readiness to implement under local conditions.

The South African agricultural sector is split into two, with medium- to large-scale commercial farmers having 50- to over 500-hectare farms, to small-scale farmers having less than 5-hectare farms. It is easier for the large-scale commercial farmers to uptake and start implementing some of these circular economy interventions but still difficult for the small-scale farmers. Government is however, intervening by assisting the small-scale farmers in areas like precision agriculture, agro-processing etc., where the Department of Science and Innovation (DSI) and the Department of Agriculture Land Reform and Rural Development (DALRRD) are assisting small-scale farmers to benefit from the services provided by these interventions.

3.2.1 Stakeholder engagement

When asked to what extent stakeholders rate the sector's readiness to implement the circular economy interventions and the level of implementation in the sector, the results showed similar responses in terms of readiness and implementation (Figure 8). Composting, crop rotation, mixed farming, agro-processing, and precision agriculture already had levels of implementation, although perhaps not yet at the scale for meaningful impact in South Africa. All other interventions were only partly implemented.

Chemical leasing, equipment sharing, digital platforms, aquaponics and vertical farming were noted by stakeholders as having lower levels of readiness for implementation. This creates an opportunity for greater research, development and innovation, together with piloting and demonstration, to show the potential opportunities for the local agricultural sector.

3.3 Challenges or obstacles to implementation

Small-scale farmers in South Africa, as in other countries, tend to be risk averse. This is understandable because for them even a small risk of crop failure is likely to have severe consequences in terms of food security (where crop failure moreover affects income security, they will look for alternative sources of income). Risk management strategies that are common in the Global North may not be available or affordable to small-holder farmers. Often farmers prefer a 'low but secure' above a 'possibly high but unsecure' production strategy. Secondly, in South Africa, many new innovations prove their value once a certain threshold of farmers have adopted the innovation and appear to stick with the changes in agricultural practices this involves. Once that has been realised, the next logical step for the innovation is to scale it up.

Bianchi *et al*. (2020) reported that scaling of innovative circular agriculture practices may be affected by a government's subsidy schemes and orientation towards export, which are likely to privilege linear approaches over more circular approaches. International trade regulations are typically value-chain based and hence limit the opportunities and incentives for the integration of value chains according to circular principles. To enable a transition towards circular agriculture, subsidy schemes, incentives and trade regulations will need to be revisited to make use of opportunities for circular agriculture at internal and external markets. He further reported that to encourage horizontal scaling, the projects had used methods often applied for first-time adoption, such as radio broadcasts, on-farm demonstrations, and farmer field schools and training centres. Termeer (2019) argues that for horizontal scaling to take place, risks and quick wins are paramount. When farmers see hands-on proof of immediate benefits, they are likely to adopt the practice, but when such quick wins are absent, many farmers are inclined to return to their conventional practices.

Scaling of an innovation is a social process in a complex reality where division of power, social stigmas and ensuring quality standards can pose significant challenges. Model farmers ('early adopters') can become the drivers of the innovation and play a crucial role in upscaling because they are respected by the community (Bianchi *et al.,* 2020). Scaling circular economy efforts in South Africa will mean triggering strategic shifts across many sectors of the economy. As noted by the CEO of Philips, "*Transitioning to a circular economy requires all of us to team up and commit to doing things differently*" (MacArthur and Van Houston, 2021).

3.3.1 Stakeholder engagement

Stakeholders provided excellent insights into the potential challenges or obstacles to scaling up and adopting these circular interventions in South Africa, as well as practical suggestions on what it would take to scale these interventions in the local agricultural sector. The main recommendations to support scaling and implementation included –

- Pilot trials of circular economy interventions (demonstration)
- Government support (financial and policy)
- Technical support
- Awareness creation and skills development
- Public procurement for circular economy products
- Public coordination and technical assistance
- Policy shift
- Digital platforms and purchase of data
- Access to relevant localised technologies
- Start-up costs for implementing circular economy technologies (equipment cost, data cost)
- Improved logistics especially in the food loss and waste sector not in place

Some of these recommendations are briefly discussed below:

Pilot trials of circular economy interventions
The analysis of responses highlights the importance of local pilot trials in showcasing circular economy interventions to stakeholders. There are however, good examples that can already be highlighted e.g., the Western Cape Department of Agriculture *Fruitlook* project – a state-of-the-art information technology that helps deciduous fruit and grape farmers to be water efficient and climate smart (WCG, 2018). This project started small with over 15,000 hectares but has expanded to over 200,000 hectares of fruit monitored weekly during the fruit growing season, with more fruit crops being added for surveillance. A second example is the Woolworths, retailer programme – a preventative approach to waste reduction through full supply chain management. By 2020, Woolworths ensured that 95% of

store waste and 100% of head offices and distribution centre waste, does not land up in landfill. If not fit for human consumption, food waste is diverted to other uses such as feed, compost or energy (WWF, 2017). Demonstration is considered critical to fast-tracking the implementation of circular interventions.

Government support

A few of the circular economy pilot projects are financed by the private sector or by entrepreneurs. Only a handful of public financing programmes (e.g., Green Fund, Green Outcomes Fund, Western Cape Government) exist to support the growth of local businesses or innovative projects in the sector. Most local circular economy pilot trials have relied on private funding or funding from international donors such as UNDP and the European Union (EU). As such, Government support, either financial or technical, could be instituted through the Department of Trade, Industry and Competition (the dtic), DSI, DALRRD, Department of Forestry, Fisheries and Environment (DFFE) or Department of Small Business Development (DSBD). However, for the sector to become sustainable, entrepreneurs and companies should be able to access conventional financing with preferential rates.

Awareness creation and skills development

Although the awareness of circular economy opportunities in South Africa is still in the early stages, the underlying concepts have received growing attention and support in recent years. However, there is still hesitation to change. The concept of the circular economy is seen as an important means of responding to some of the country's critical and interlinked development challenges, ranging from unemployment, poverty and inequality, to water and energy security, and climate change. In recent years, a number of awareness creation initiatives for circular economy-related measures were launched in South Africa. In addition to state-organised donor- and state-funded initiatives, social entrepreneurs in South Africa are increasingly involved in awareness-raising efforts for the circular economy. Awareness creation should be raised among key public and private sector stakeholders by building capacity of national extension units, technical advisers, farmers and other key stakeholders to promote sustainable agriculture practices and alternatives to agrochemical inputs.

South Africa's higher education institutions (HEI) show increased efforts to implement sustainable development and global change related knowledge areas in existing teaching programmes. However, the approach of HEIs are usually poorly coordinated and harmonized, highly depending on lecturers' interest, thus being mostly inadequate to meet the skills demand for an emerging green and circular economy (DEFF, 2020). The National Curriculum (Vocational) (NCV) makes some provision for training in sustainable agriculture and eco-tourism, but lecturers often lack the necessary knowledge and the resources to teach these subjects adequately. Skills like precision agriculture are scarce skills. The CSIR has developed an internal internship programme where they train most of their employees from Honours to PhD.

Public procurement

The role of public procurement in the circular economy could be significant, with increased public procurement substantially increasing the demand for circular economy products and services. Circular procurement is the process by which public authorities purchase works, goods or services that seek to contribute to closed energy and material loops within supply chains, whilst minimising, and in the best case avoiding, negative environmental impacts and waste creation across their whole life cycle. Examples include: purchasing recycled materials instead of virgin materials, or purchasing a service instead of a product. Public procurement can also drive greater awareness of environmental considerations. A mandatory set of criteria would effectively enforce the significance of environmental considerations in the procurement process. The EU, for example, is regulating public procurement through the Directive on Public Procurements (2014/24/EU 2017). The South African government could similarly consider incorporating the circular economy into its Public Procurement Policy.

Public coordination

This involves proper coordination among the key departments DALRRD, dtic, DFFE, DSI, and DSBD. Departments that have a circular economy mandate should be collaborating and working together to create a systems response for the benefit of the country.

Policy shift

Government's position on science, technology and innovation (STI) for a circular economy, is outlined in the White Paper on STI. The agricultural sector does not have bold policies and legislation to support the circular economy. However, a transition to a circular economy remains a priority for the DSI, embedded as a key tenet of the STI Decadal Plan, which will serve as an implementation plan over the period 2022-2031. South Africa already benefits from the implementation of a 10-year national Waste Research, Development and Innovation (RDI) Roadmap with the vision to stimulate waste innovation (technological and non-technological), Research and Development, and Human Capital Development (HCD), through investment in science and technology. In doing so, it aims to maximise diversion of waste from landfill towards value-adding opportunities, including prevention of waste and the optimised extraction of value from reuse, recycling and recovery, in order to create significant economic, social and environmental benefit (CSIR 2012). The Agriculture and Agro-processing Master Plan being developed by government, provides an opportunity to realign to the National Development Plan inclusive agricultural and agro-processing transformation and the circular economy (DALRRD 2021).

3.4 Addressing resource constraints, while unlocking environmental, social and economic opportunities

The circular economy is recognized as an opportunity to decouple economic development from resource consumption, while also creating very real environmental and socio-economic benefits. The European Commission (EC) estimates jobs directly associated with the circular economy to be 3.9 million (EC, 2018). The ILO projects the net creation of 18 million green jobs by 2030, while the Global Climate Action Summit estimated the creation of over 65 million new low-carbon jobs by 2030 (ILO, 2018). A modelling exercise undertaken by Potgieter *et al.* (2020) showed that a shift to a circular economy in managing food waste, could lead to the creation of 17,000 new jobs in South Africa by 2030. The ILO describes green jobs as part of the Decent Work Agenda, which is a globally recognized framework for poverty reduction and inclusive development. A decent job involves opportunities for work that is productive and delivers a fair income; provides security in the workplace and social protection for workers and their families; offers better prospects for personal development and encourages social integration; gives people the freedom to express their concerns, to organize and to participate in decisions that affect their lives; and guarantees equal opportunities and equal treatment for all (ILO, 2019).

While there is no quantitative data, as yet, on the number of jobs that can be created through circular economy interventions in the broader South African agricultural sector, stakeholders generally agreed that circular economy interventions have the potential to create net jobs through inclusive growth:

- "*Increased localisation will lead to more jobs. Sourcing of the right technologies and skills development will create new jobs*"
- "*Creating agro-processing companies to reduce food waste will result in new jobs*"
- "*Exploring more opportunities on waste streams generated through commercial agriculture, will create jobs*".
- "*Creation of new business and employment opportunities including substitution, elimination, transformation and redefinition.*"
- "*Increase urban farming using controlled environmental agriculture will create urban jobs*"
- *"Formal and informal training and skills development especially in the waste management, renewable energy, agro-processing sectors."*

Stakeholders also provided their thoughts on how the implementation of circular economy interventions in the South African agricultural sector could mitigate detrimental environmental impacts. These included –

- *"Installation of renewables – clean, renewable energy systems, such as solar and wind, can reduce your impact on the environment significantly while lowering your energy bill."*
- *"Processing and recycling of wastewater from packing stations."*
- *"Reduce, reuse, recycle. Your environmental footprint goes beyond energy use and your business."*
- *"Building soil organic matter, conserving soil moisture and reducing water consumption"*
- *"Reducing the carbon footprint of operations, reducing GHG emissions, increasing renewable energy generation"*
- *"Reducing or eliminating chemical leakage"*

3.5 Business opportunities to implement these circular economy solutions

Research shows that the circular economy has the potential of offering globally $4.5 trillion in economic opportunity, by creating new business models that focus on designing out waste and pollution; keeping products and materials in use; and regenerating natural systems. It also offers significant innovation opportunities (McGinty 2021). Some of the immediate business opportunities in the sector include:

- *Organic waste beneficiation:* Food losses and waste is a growing reality, estimated to be in the order of 10.3 million tons in 2021 (Oelofse *et al*., 2021). Not only is food wasted, but all the energy and inputs required to grow, package and transport the wasted food are also lost. Organic waste from farming has long been used as a source of fertiliser for agriculture. Biological waste such as crop stalks, leaves, pods, fruits and vegetables that cannot make it to the markets and animal waste can be converted into fertilisers which are rich in nitrogen, phosphorous, potassium and other nutrients and can reduce the cost and resource demand for external inputs of synthetic fertilisers. South African homes have small gardens of 100-500 square meters. Many plant fresh vegetables in these gardens and organic compost is ideal for such gardens because it improves the soil nutrients, soil texture, encourages the growth of beneficial soil microorganisms and water holding capacity of the soils. Big and small businesses can be created to supply compost in rural communities. Infrastructure for food redistribution and collection can create new businesses. This can also include digital infrastructure to support food networks. Digital technologies (block chain, sensor technologies) will play a key role in increasing traceability and linking value chain players across regions (Figure 9).

- Biochar, can be produced as a by-product of pyrolysis / gasification of waste biomass. Biochar shows great potential to reduce the environmental impact, address climate change, and establish a circular economy model.

- *Energy generation:* From the same plant biomass, animal waste can also be added to the biomass to generate energy which can be used for cooking especially in rural communities and biofuel from waste from e.g., sugarcane or sweet sorghum.

- *Animal manure management* – Pig, cow, etc. manure can be converted into valuable fertilizers with water recovery.

Other business opportunities, which will require more support to establish or scale, include:

- *Regenerative agriculture* is a system of farming practices and principles that increases ecosystem health while improving yields (Schindler 2021). Some ways that businesses from various industries can start contributing to regenerative agriculture include:

    - Increasing the educational opportunities for those in the agricultural industry and consumers to increase interest in regenerative agriculture.
    - Providing technical tools and farmer training can support the transition to regenerative agriculture methods.
    - Creating improved tools and technology that can establish a resilient market for regeneratively grown food.

- *Precision agriculture* which uses remote sensing and data collection to ensure the right amount of resources (water, fertilizers, pesticides) are used at the right time in exactly the right place. The technology can also be used to predict yield.

- *Agro-processing technologies* for value add

- *Biorefinery* and high-value product recovery from agro-industrial waste streams

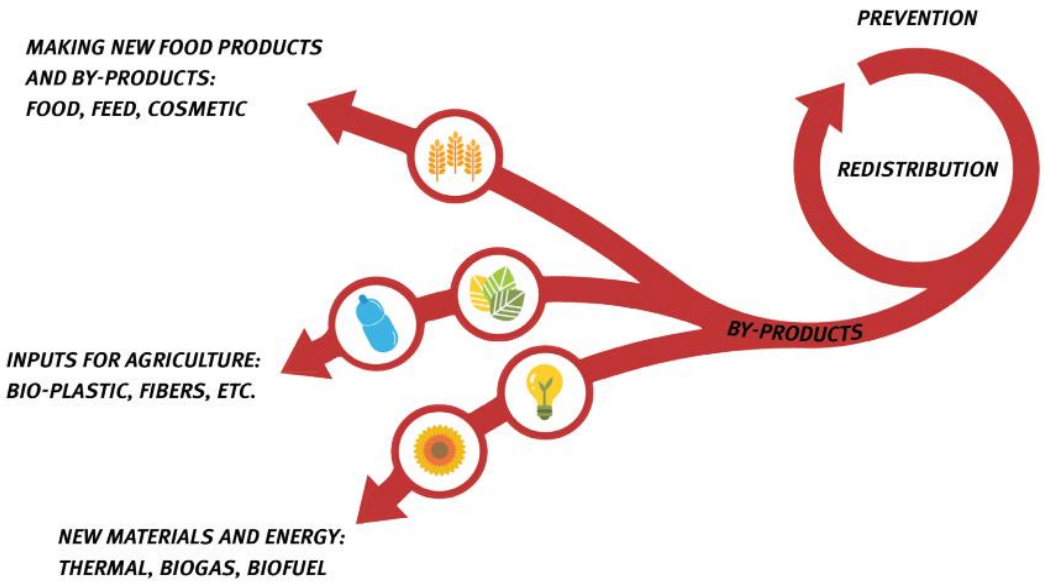
- *Equipment sharing* and *chemical leasing*

- *Urban farming* – vertical farming, aquaponics, aquaculture, greenhouse farming, etc.

3.6 Potential for climate change mitigation

Climate change is now emerging as the most severe challenge facing our planet and requires efforts from science, decision-makers in the public sector, and society. We need a fundamental shift in the global approach to climate change to reduce GHG emissions and meet the targets set out in the Paris Agreement by 2050. The circular economy represents a promising alternative to deliver GHG emissions reductions by changing the traditional production and consumption model for a more sustainable one (Stahel, 2016).

Globally, agriculture (cultivation of crops and livestock) and deforestation are key contributors to climate change, being responsible for about 11.9% of all GHG emissions (EPA 2021). The benchmark National GHG Emissions Trajectory Range: 6.4.1 reflects South Africa's fair contribution to the global effort to limit anthropogenic climate change to well below a maximum of 2°C above pre-industrial levels. South Africa's GHG emissions peak in the period 2020 to 2025 is in a range with a lower limit of 398 Megatonnes (109 kg) (Mt) CO_2 -eq and upper limits of 583 Mt CO_2 -eq. From 2036 onwards, the country will lower emissions in absolute terms to a range with lower limit of 212 Mt CO_2 eq and upper limit of 428 Mt CO_2-eq by 2050 (DFFE, 2018).



Source: https://www.ellenmacarthurfoundation.org/explore/food-cities-the-circular-economy

Figure 9. Business opportunities from food waste

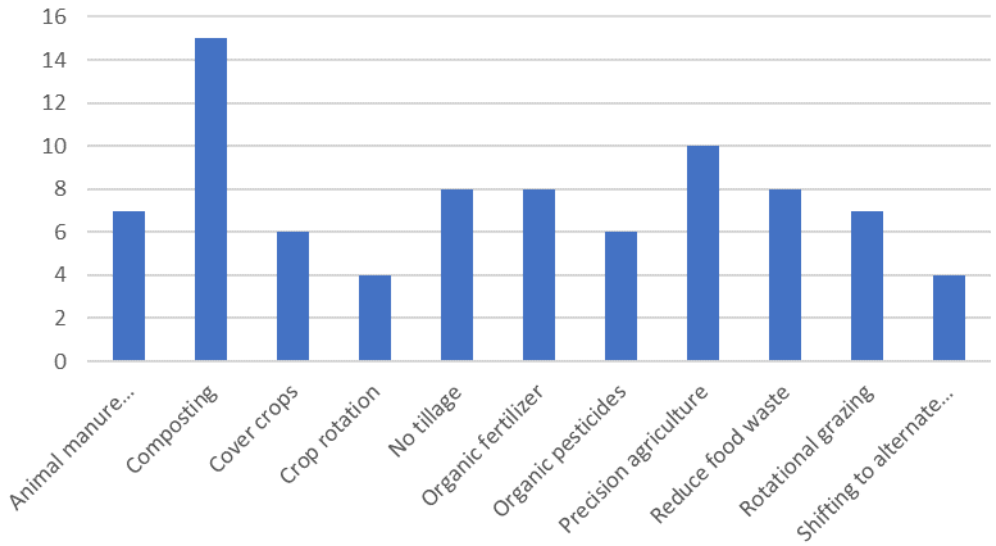


Figure 10. Circular economy interventions to reduce greenhouse gas emissions

When the question was posed to stakeholders on what circular economy interventions could reduce GHG, there was general consensus on regenerative agriculture interventions (crop rotation, minimum tillage, green manure, integrated pest management) which were seen as providing an opportunity to reduce GHGs, land degradation and water use, while boosting farmer income and welfare. Closing the loop on organic waste by composting it and shifting to alternative protein sources and sustainable diets were other favourites (Figure 10).

3.7 Summary

This second part of the report has looked at identifying innovative circular economy interventions; assessing the appropriateness of these interventions for South Africa; critically assessing the readiness (including potential obstacles and unintended consequences) to implement these circular economy solutions; assessing the business opportunities to implement these circular economy solutions; and analysing how these circular economy interventions could address resource constraints, while unlocking environmental, social and economic opportunities. And finally providing an indication of the GHG mitigation potential of the various interventions.

On circular economy interventions, stakeholders agreed on the more commonly practiced interventions. These included precision agriculture, agro-processing, composting, and packaging technologies. Reducing food losses and waste was also emphasised. There was some level of uncertainly with regards to the less familiar interventions, such as chemical leasing, zero tillage, equipment sharing, vertical farming, and digital platforms.

A similar response trend was seen on the readiness of implementing these interventions in South Africa, where composting, crop rotation, mixed farming and agro-processing already had levels of implementation in South Africa. More work will need to be done on raising the levels of awareness in the agricultural sector on chemical leasing, equipment sharing, and aquaponics.

Overcoming challenges and obstacles to scaling up included the need for pilot trials (demonstration) of circular economy interventions; government support (financial and policy); awareness creation and skills development (education and training); public procurement for circular economy products and services; public coordination and technical assistance; policy shift; digital platforms; and improved access to relevant localised technologies.

Business opportunities ranged from improved food waste management; regenerative agriculture interventions; precision agriculture, agro-processing, equipment sharing, to urban farming.

Stakeholders identified climate change as a severe challenge facing our planet and the agricultural sector. Mitigations proposed were generally towards regenerative agriculture interventions (crop rotation, minimum tillage, green manure, integrated pest management) that can reduce GHGs, land degradation and water use. It is also important to note that South Africa's GHG emissions peak in the period 2020 to 2025 is in a range with a lower limit of 398 Megatonnes (109 kg) (Mt) CO_2 -eq and upper limits of 583 Mt CO_2 -eq.

4 Conclusions

Circular agriculture is not a new concept and was widely practiced by pre-industrial societies. However, it has been pushed aside by modern farming based on large-scale, monoculture and highly intensive practices, which are often primarily focused on maximizing profit over the protection of the environment. The business model of large-scale, specialised agricultural establishment is currently not well suited for circular agriculture. With time, big farms and businesses in the sector will have to transform to be sustainable and economically viable. Customers are generally well-informed with the ability to influence market trends.

Agriculture plays an important role in the South African economy, with the sector being deeply interconnected and central to many other industries and their operations. South Africa is a major producer and exporter of agricultural products, and the country has consistently remained a net exporter over the last decade, with agricultural exports amounting to USD10.2 billion in 2020 and a record USD12.4-billion in 2021 creating 829,000 jobs. However, the agricultural sector is resource intensive, with a heavy reliance on water, energy, soil, nutrients, and natural cycles, as primary inputs.

To feed a growing South African population will require embracing new farming methods that could help the agriculture industry reduce its environmental impact while still increasing productivity. While previous evolutions in farming have largely been driven by mechanical improvements (namely, bigger, better machinery), genetic advances (improved seeds), and green revolution (more effective fertilizers, etc.), the next big transformation is being driven by digital tools and lifestyle changes that will force the sector to think differently. A number of new, disruptive, technology trends that are emerging in the agricultural sector, and are regarded as key market opportunities, have been highlighted in the report. Implementation of these transformative technologies requires a collective approach from all stakeholders.

Engagement with sector stakeholders showed that many are already engaging with the topic of a circular economy in agriculture and are aware of most of the circular economy interventions. However, a few were uncertain with regards to the less familiar interventions, such as chemical leasing, zero tillage, equipment sharing, vertical farming and digital platforms. The South African agricultural sector is ready and has already started implementing some of these circular economy interventions, although at different scales. There are a few interventions that will take longer to implement due to certain challenges facing the sector.

Financing appeared to be the most persistent vital barrier. Stakeholders cited the high upfront investment costs in some interventions. Enterprises are mostly profit-oriented, and profits come before environmental considerations. However, for the sector to become sustainable, entrepreneurs and companies should be able to access conventional financing with preferential rates. The second highest point was the need for pilot or demonstration studies, to create an opportunity for farmers to see the circular interventions in practice. In addition, government needs to consider appropriate policies, including public procurement, that will favour growth and circular economy interventions in the sector. Awareness creation and access to appropriate technologies were also needed to overcome barriers in scaling.

Business opportunities ranged from improved food waste management (reducing food losses and waste to unavoidable food waste beneficiation); regenerative agriculture interventions; precision agriculture; agro-processing; equipment sharing; to urban farming.

Finally, stakeholders identified climate change as a major challenge facing the sector. Circular agricultural practices were seen as an opportunity for the sector to mitigate its climate impacts through regenerative agriculture interventions such as crop rotation, minimum tillage, green manure, and integrated pest management.

5 References

Agrocycle (2017). The Project Agrocycle. http://www.agrocycle.eu.

BFAP (2021). Perspective on agriculture's performance in Quarter 4 of 2020, Bureau for Food and Agricultural Policy. *https://www.bfap.co.za/perspectives-on-agricultures-gdp-performance-in-q4-2021/*

Bianchi, F., van Beek, C., de Winter, D. and Lammers, E. (2020). Opportunities and barriers of circular agriculture. *https://www.nwo.nl/sites/nwo/files/documents/1.%20Circular%20agriculture_full%20paper.pdf*

Business Wire (2021). South Africa Fertiliser and Nitrogen Compounds Industry Report 2021 – Research and Markets.com. *https://www.businesswire.com/news/home/20210902005493/en/South-Africa-Fertiliser-and-Nitrogen-Compounds-Industry-Report-2021*

CSIR (2012). Waste RDI roadmap for South Africa. https://www.csir.co.za/developing-waste-rdi-roadmap.

CSIS (Centre for Strategic and International Studies) (2022). Agriculture and Food Security: Casualties of the War in Ukraine. Available online at *https://www.csis.org/analysis/agriculture-and-food-security-casualties-war-ukraine*

Department of Agriculture, Land Reforms and Rural Development (DALRRD) (2021). Minister Didiza meets Agriculture and Agro-Processing Stakeholders for further discussions of the Agriculture and Agro-Processing Master Plan (AAMP). *https://www.gov.za/speeches/gro-processing-stakeholders-further-discussions-agriculture-29-mar-2021-0000*

Department of Energy (DoE) (2019). The South Africa Energy Sector Report. Available online at *http://www.energy.gov.za/files/media/explained/2019-South-African-Energy-Sector-Report.pdf*

Department of Environmental Affairs (DEA) (2011). South Africa's second national communication under the United Nations framework convention on climate change. DEA: Pretoria.

Department of Environmental Affairs (DEA) (2020). Environmental Sector Skills Plan For S. Africa.

Department of Forestry, Fisheries and Environment (DFFE) (2018). An Analysis of Projected Greenhouse Gas Emissions Pathways. https://www.dffe.gov.za/sites/default/files/docs/session3_projecctedemissionpathways.pdf

Department of Mineral Resources and Energy (DMRE) (2021). The South African Energy Sector Report.

Du Preez, C.C., Van Huyssteen, C.W., Mnkeni, P.N. (2011). Land use and soil organic matter in South Africa 1: A review on spatial variability and the influence of range land stock production. *S Afr J Sci.* 107(5/6), Art. #354, 8 pages. doi:10.4102/sajs.v107i5/6.354.

Ellen MacArthur Foundation (2016). Circular Economy in India: Rethinking growth for long-term prosperity, *http://www.ellenmacarthurfoundation.org/publications/*

EPA (2021). Sources of Greenhouse Gas Emissions. *https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions*

European Commission (2017). Public procurement for a circular economy. *https://ec.europa.eu/environment/gpp/pdf/*

European Commission. (2018). Circular Economy Package. Available from *http://ec.europa.eu/environment/circular-economy/index_en.htm*

FAO (2020). Country profile, South Africa *http://www.fao.org/3/x9751e/x9751e07.htm*

Godfrey, L. (2021). The circular economy as development opportunity. CSIR: Pretoria.

GreenCape (2021). Water market intelligence report. Cape Town, South Africa. Available online at *https://www.greencape.co.za/assets/WATER_MIR_2021_31_3_21.pdf*

Gwenzi, W., Chaukura, N. (2018). Organic contaminants in African aquatic systems: current knowledge, health risks, and future research directions. *Sci. Total Environ*., 619–620 (2018), pp. 1493-1514.

Hardy, M., Dziba, L., Kilian, W., and Tolmay, J. (2011). Rainfed farming systems in South Africa In: Tow, P, Cooper, I. Partridge, I, Birch, C (Eds.), *Rainfed Farming Systems*, Springer, Netherlands, Dordrecht (2011), pp. 395-432, 10.1007/978-1-4020-9132-2_16.

Hoffman, T. and Ashwell, A. (2001). Nature divided: land degradation in South Africa, *Land Degradation and Development,* 12:572-572.

International Institute for Sustainable Development (IISD) (2020). Effects of the Circular Economy on Jobs *https://www.iisd.org/system/files/2020-12/circular-economy-jobs.pdf*

International Labour Organization. (2018). Decent work. *https://www.ilo.org/global/ topics/decentwork/lang--en/index.htm*

Johnson, P. (2019). Farming in South Africa is under threat from climate change. Here's how. *https://mg.co.za/article/2020-01-07-farming-in-south-africa-is-under-threat-from-climate-change-heres-how/*

Knoema (2021). South Africa - Fertilizer consumption per unit of arable land. *https://knoema.com/atlas/South-Africa/Fertilizer-consumption*

Kuschke, I. and Shai, T. (2021). GreenCape Sustainable Agriculture – Market Intelligence Report *https://www.greencape.co.za/assets/SUSTAINABLE_AGRI_MIR_2021_14_4_21.pdf*

MacArthur, E. and Van Houston, F. (2021). 3 shifts can scale the circular economy – triggering a more resilient, prosperous system. *https://www.weforum.org/agenda/2021/02/3-shifts-can-scale-the-circular-economy-ellen-macarthur-frans-van-houten/*

Marr, B. (2022). The Biggest Future Trends In Agriculture And Food Production. *https://www.forbes.com/sites/bernardmarr/2022/01/28/the-biggest-future-trends-in-agriculture-and-food-production/?sh=d00fff8107a2*

Masiwa, D. (2019). Small-scale farmer support programme gives rural farmers a second chance. *https://www.foodformzansi.co.za*

Mateo-Sagasta, J., Zadeh, S.M., and Turral, H. (2018), More People, More Food, Worse Water?: A Global Review of Water Pollution from Agriculture, Rome, Italy: FAO:

International Water Management Institute (IWMI), *http://www.fao.org/3/CA0146EN/ca0146en.pdf*

McGinty, G. (2021). Five Opportunities of a Circular Economy. *https://www.wri.org/insights/5-opportunities-circular-economy*

Msimanga, X., Godfrey, L. and North, B. (2021). Decoupling South Africa's development from energy demand through a more circular economy. pp 53-61. In '*The circular economy as development opportunity*'. Edited by L. Godfrey. CSIR 80p.

Mtulu, X. and de Lange, A. (2021). The agricultural sector in 2021, a positive outlook? *https://www.cliffedekkerhofmeyr.com/en/news/publications/2021/Agri/agricultural-alert-22-september-the-agricultural-sector-in-2021-a-positive-outlook.html*

Oelofse, S.H.H. (2014). Food waste in South Africa: Understanding the magnitude, water footprint and cost. In: *The vision zero waste handbook South Africa.* Vol. 4. Alive2green: Cape Town, South Africa. *https://researchspace.csir.co.za/dspace/bitstream/handle/10204/8367/Oelofse1_2014.pdf*

Oelofse, S.H.H., Muswema, A.P. and Ramukhwatho, F.R. (2018). Household food waste disposal in South Africa: A case study of Johannesburg and Ekurhuleni. *SAJS* 114(5/6): *doi.org/10.17159/sajs.2018/20170284*.

Oelofse, S., Polasi, T., Haywood, L. and Musvoto, C. (2021). Increasing reliable, scientific data and information on food losses and waste in South Africa. Pretoria: CSIR. *https://wasteroadmap.co.za/wp-content/uploads/2021/06/17-CSIR-Final_Technical-report_Food-waste.pdf*.

Okole, B., Gordon, G., Brown, B., Pillay, B., Schoeman, C. (2021). Supporting food security and economic development through circular agriculture pp 18-26. In '*The circular economy as development opportunity*'. Edited by L. Godfrey. CSIR 80p.

Osibanjo, O., Bouwman, H., Bashir, N.H.H., Okond'Ahoka, J., Choong Kwet Yve, R. and Onyoyo, H.A. (2002). Regionally based assessment of persistent toxic substances: sub-Saharan Africa regional report. UNEP Chemicals, Geneva.

Onyoyo, H.A. (2002). Regionally based assessment of persistent toxic substances. SubSaharan Africa regional report. UNEP Chemicals, Geneva.

PAN (2010). PAN Pesticide database, 20.03.2011, Available from *http://www.pesticideinfo.org*

PAN (2022) Pesticides are the lynchpin of an unsustainable industrial agriculture system. *https://www.panna.org/pesticides-big-picture/lynchpin-industrial-ag*

Paterson, G. (2017). Trends in South African agriculture. *https://www.arc.agric.za/arc-iscw/News%20Articles%20Library/Trends%20in%20SA%20agriculture.pdf*

Potgieter, J.E., Rajput, J., Hemkhaus, M., Ahlers, J., Van Hummelen, S., McGovern, M. and Artola, I. (2020). Circular economy in the Africa-EU cooperation – Country Report for South Africa. Country report under EC Contract ENV.F.2./ETU/2018/004 Project. *http://trinomics.eu/wp-content/uploads/2020/12/Country-Report-South-Africa_Final_20122020.pdf*

Quantec (2020). Regional Service:RSA Standardised Regional. Easy Data, Quantec, Pretoria.

SA Government (2022). Agriculture, land reform and rural development. *https://www.gov.za/about-sa/agriculture*

Schinder, W. (2021) Food: A Circular Economy Investment Opportunity For Companies. *https://www.forbes.com/sites/forbesbusinesscouncil/2021/05/19/food-a-circular-economy-investment-opportunity-for-companies/?sh=3ab846e923b3*.

Scholten, M. (2021). Circular agrofood system. *https://www.wur.nl/en/Dossiers/file/Circular-agrofood-system.htm*

Sihlobo, W. (2021). South Africa's agricultural exports registered the second largest level on record in 2020. SA Weekly Agricultural Viewpoint. Available online at *https://agbiz.co.za/content/open/15-february-2021-agri-market-viewpoint*

Sihlobo, W. (2022). After two years of growth, SA's agricultural economy could contract. *https://mg.co.za/opinion/2022-03-15-after-two-years-of-growth-sas-agricultural-economy-could-contract/*

Stahel, W.R. (2016) The circular economy. Nature: 531, 435–438.

StatsSA (2020). Census on commercial agriculture *http://www.statssa.gov.za/?p=13144*

StatsSA (2021). These goods drive South African agriculture. *http://www.statssa.gov.za/?p=14370*

Termeer, K. (2019). Het bewerkstelligen van een transitie naar kringlooplandbouw. Wageningen, The Netherlands. Wageningen University & Research

UN/DESA (2021): Circular agriculture for sustainable rural development- *https://www.un.org/development/desa/dpad/publication/un-desa-policy-brief-105*.

UNEP (2009). Water sustainability of agribusiness activities in South Africa. Chief Liquidity Series 1,42-48

UNEP (2021). Food Waste Index Report *https://www.unep.org/resources/report/unep-food-waste-index*

US International Trade and Administration (2022) South Africa - Country Commercial Guide -Agriculture sector. *https://www.trade.gov/country-commercial-guides/south-africa-agricultural-sector*

Western Cape Government (WCG) (2018). Case Study Fruitlook. A state-of-the-art information technology that helps deciduous fruit and grape farmers to be water efficient and climate smart. Available at: *https://www.greenagri.org.za/assets/documents-/SmartAgri/Case-Studies/1.-Case-Study-FruitLook-FINAL.pdf*

World Bank Group (2022). Background of our work in South Africa. *https://www.2030wrg.org/south-africa/background/*

WWF (2017). Food Loss and Waste: Facts And Futures Taking Steps Towards A More Sustainable Food Future. *http://awsassets.wwf.org.za/downloads/WWF_Food_Loss_and_Waste_WEB.pdf*

Appendix 1: Survey Questionnaire

CIRCULAR ECONOMY INTERVENTIONS FOR THE SOUTH AFRICAN AGRICULTURE AND FOOD SECTOR

Dear Participant

You have been selected to participate in this study because you have valuable knowledge about the South African Agriculture and Food Industry.

The agriculture and food industry relies heavily on resources and natural cycles as its primary inputs. Resources such as water, energy, soil, and nutrients underpin the functioning of the ecosystem in which the sector operates. Growing food demand and high population growth has resulted in environmental challenges such as climate change, deforestation and rapid expansion of human settlements resulting in biodiversity loss and land degradation, impacting negatively on food security. The intention of this questionnaire is to initiate discussions on:

- the potential opportunities that a more circular agriculture system may provide South Africa.
- the appropriateness of these interventions for South Africa.
- potential obstacles to their uptake; and
- the readiness to implement these solutions in South Africa.

These opportunities are framed within the context of the current challenges facing the South African agricultural sector. It would thus be appreciated if you would be willing to participate in this survey, which should take about 15-20 minutes to complete.

You are kindly requested to complete the questionnaire based on your knowledge and experience regarding circular economy practice within the agriculture and food sector. The information provided will remain completely confidential and the anonymity of respondents will be retained indefinitely.

If required, you may contact any of the following representatives regarding the survey:

Name	Role	Contact details
Blessed Okole	Project Lead (Agriculture and Food)	*bokole@csir.co.za*
Chanel Schoeman	Project Team (CO PI)	*CMSchoeman@csir.co.za*

1. PART 1: DEMOGRAPHICS/PROFILE

In this section, we would like to request information about your company/organization

1.1. Please select the category to which your organization belongs.

Type of Organization	Private Sector	Government	NGO	Other

If other, please specify: _____

1.2. How many years of experience do you have working in the South African agriculture and food sector?

Sectoral experience	<1 year	1-2 years	3-4 years	5-10 years	>10 years

1.3. Please indicate your main level of responsibility within your organization?

Level of Responsibility	Please tick
Executive	
Senior Manager	
Manager	
Field Technician	
Research and Development	
Other	

If other selected, please specify: _____

1.4. Please indicate the number of employees within your organization

No of employees	Please tick
<10	
11-50	
51-100	
101-500	
>500	

2. PART 2: CIRCULAR ECONOMY EXPERIENCE

'Circular agriculture' interventions centre on:

i. a regenerative system, with the production of agricultural commodities using a minimal amount of external inputs;
ii. decoupling production and processing from resource utilization;
iii. closing nutrient loops;
iv. restoring soil fertility; and
v. reducing discharges to the environment.

This survey seeks to appraise a number of proposed circular economy interventions for the South African agriculture and food sector.

2.1. Please rate your personal knowledge of the Circular Economy (CE).

CE Knowledge	None	Novice	Working	Good	Excellent

2.2. Are you currently (or have you previously been) involved in Circular Economy related projects and/or interventions?

Yes		No	

2.3. How many years of experience do you have with Circular Economy (CE) related projects?

CE Involvement	<1 year	1-2 years	3-4 years	5-10 years	>10 years

2.4. Please elaborate on any Circular Economy related projects you are or have been involved in.

_____

3. PART 3: PROPOSED CIRCULAR ECONOMY INTERVENTIONS

Circular economy interventions can broadly be categorised under three principles:

i. designing out waste and pollution;
ii. keeping materials and products in use, and
iii. regenerating natural systems.

In this section, we would like to assess the following:

- whether you agree with the proposed Circular Economy interventions,
- your personal views regarding key interventions to be implemented or scaled,
- what you consider as enablers for the implementation of Circular Economy activites, and
- some of the challenges/barriers to the implementation of Circular Economy activities within the South African agriculture and food sector

Based on your personal knowledge and experience with the Circular Economy, please provide responses to the following questions or statements.

3.1. In your opinion, on ***which*** resources (e.g. energy, water, fertilisers, pesticides) does the SA agriculture and food sector strongly depend on?

_____

3.2. Which of the following Circular Economy Interventions are you familiar with?

Circular Economy Intervention	**Unfamiliar**	**Partly Familiar**	**Familiar**	**Very familiar**
Agro-processing technologies				
Anaerobic digestion & Biogas production				
Aquaponics/ Aquaculture				
Chemical Leasing				
Composting				
Equipment sharing (Sharing economy – eg. machine sharing)				
Intercropping/crop rotation				
Mixed farming				
Mobile or digital platforms				
Packaging technologies for shelf life				
Precision agriculture				
Urban and Peri urban farming				
Vertical farming / Vertical agriculture				
Zero tillage				

3.3. Are there other Circular Economy interventions in the agriculture and food sector that you consider important that may have been omitted from above list? Please elaborate

_____

3.4. Which of the listed Circular Economy interventions would you say are already being implemented within the South African agriculture and food sector or broader economy?

Circular Economy Intervention	**Not Implemented**	**Partly Implemented**	**Implemented**
Agro-processing technologies			
Anaerobic digestion & Biogas production			
Aquaponics/ Aquaculture			
Chemical Leasing			
Composting			
Equipment sharing (Sharing economy – eg. machine sharing)			
Intercropping/crop rotation			
Mixed farming			
Mobile or digital platforms			
Packaging technologies for shelf life			
Precision agriculture			
Urban and Peri urban farming			
Vertical farming / Vertical agriculture			
Zero tillage			
Other:			

Please elaborate on your responses above, particularly where you consider any of these interventions are **already implemented**

_____

3.5. To what extent do you agree that the following Circular Economy interventions can benefit the South African agriculture and food sector?

Circular Economy Intervention	**Disagree**	**Agree**	**Strongly Agree**
Agro-processing technologies			
Anaerobic digestion & Biogas production			
Aquaponics/ Aquaculture			
Chemical Leasing			
Composting			

Circular Economy Intervention	Disagree	Agree	Strongly Agree
Equipment sharing (Sharing economy – eg. machine sharing)			
Intercropping/crop rotation			
Mixed farming			
Mobile or digital platforms			
Packaging technologies for shelf life			
Precision agriculture			
Urban and Peri urban farming			
Vertical farming / Vertical agriculture			
Zero tillage			
Other:			

3.5.1. Which ***potential benefits*** could the Circular Economy provide to the South African agriculture and food sector?

_____

3.6. How would you rate the South African agriculture and food sector in terms of readiness towards implementing the proposed Circular Economy interventions listed below.

Circular Economy Intervention	Not Ready	Partly Ready	Ready
Agro-processing technologies			
Anaerobic digestion & Biogas production			
Aquaponics/ Aquaculture			
Chemical Leasing			
Composting			
Equipment sharing (Sharing economy – eg. machine sharing)			
Intercropping/crop rotation			
Mixed farming			
Mobile or digital platforms			
Packaging technologies for shelf life			
Precision agriculture			
Urban and Peri urban farming			
Vertical farming / Vertical agriculture			
Zero tillage			
Other:			

Please elaborate on your response above, particularly where you consider the sector is **not ready**

_____

3.7. What would you consider are the main obstacles towards the implementation of the proposed Circular Economy interventions for the South African agriculture and food sector? Please list possible obstacles

_____

3.8. ***Which*** Circular Economy interventions – if implemented within the SA agriculture and food sector – could ***improve the resilience and competitiveness*** of the sector***?***

_____

3.8.1. ***How*** would the implementation of these Circular Economy interventions in the SA agriculture and food sector ***improve the resilience and competitiveness***?

_____

3.8.2. ***What would be required to enable implementation*** of these Circular Economy interventions within the SA agriculture and food sector?

_____

3.9. ***Which*** Circular Economy interventions – if implemented within the SA agriculture and food sector – could lead to ***inclusive growth and decent jobs?***

_____

3.9.1. ***How*** would the implementation of these Circular Economy interventions in the SA agriculture and food sector lead to ***inclusive growth and decent jobs***?

_____

3.9.2. ***What would be required to enable implementation*** of these Circular Economy interventions within the SA agriculture and food sector?

_____

3.10. ***Which*** Circular Economy interventions – if implemented within the SA agriculture and food sector – could ***mitigate environmental pollution***?

_____

3.10.1. ***How*** would the implementation of these Circular Economy interventions in the SA agriculture and food sector ***mitigate environmental pollution***?

_____

3.10.2. ***What would be required to enable implementation*** of these Circular Economy interventions?

_____

3.11. ***Which South African policies/strategies/legislation*** support Circular Economy interventions in the SA agriculture and food sector?

_____

3.11.1. ***How*** do these ***policies/strategies/legislation*** support Circular Economy interventions in the SA agriculture and food sector ***mitigate environmental pollution***?

_____

3.11.2. ***What gaps*** exist in the current policy landscape that need to be filled in order to facilitate Circular Economy interventions in the SA agriculture and food sector?

_____

3.12. ***What*** *would be* ***required*** *to enable* the SA agriculture sector to readily adopt ***regenerative agriculture*** such as indigenous knowledge based practices?

_____

3.13. To fast-track/implement of some Circular Economy interventions, the SA agriculture and food sector would require access to what ***digital infrastructure***?

_____

3.14. Please provide any additional information you consider relevant to the implementation of the Circular Economy within the South African agriculture and food sector

_____

3.15. **OPTIONAL:** Please complete the following personal information (*NB: all information provided will remain confidential*).

Full Name: _____

Company/organization: _____

Would you be willing to be interviewed (if needed) to discuss the above issues in further detail?

Yes		No	

Thank you for your participation in this questionnaire, your insights are highly valued!!

Privacy Statement

Introduction:

- This privacy statement will inform you what the CSIR will do with the Personal Information it collects from you and which you voluntarily provide to the CSIR, it also indicates your rights as a data subject.
- The Personal Information required for this study is strictly the name of your organization, email address and telephone number.
- The CSIR will use such Personal Information only for purposes of further engagements with you, based on outcomes of the study, and to share any relevant innovation & technology developments in its portfolio.
- You may opt-out of sharing your Personal Information and still be able to continue with the study anonymously.
- Data collected is strictly for the CSIR's internal use and will not be shared nor transferred to any third parties.

Read more **click here**

- ◉ Yes I want to participate
- ○ No thank you, I do not want to participate