Briefing Note 2021/003

November 2021

# Supporting food security and economic development through circular *agriculture*

**Circular Economy Briefing Note No. 3 in a series of 8**

The intention of this short think piece on the circular economy in agriculture, is to initiate discussion on the sector opportunities for South Africa. These opportunities are framed within the context of the current challenges facing the South African agricultural sector.

*"Circularity in agriculture has to be reachable and it has to be tangible. It needs to be a thing that people will embrace because they can afford it, and because they see its value*". (Footprint Africa)[25]

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## Introduction

The agriculture 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 in South Africa. Growing food demand and environmental challenges such as climate change, land degradation, biodiversity loss, and resource scarcity are increasingly pressurizing the agricultural system, impacting food security. The sector currently faces numerous challenges. Climate change is directly affecting agricultural productivity in South Africa through changes in precipitation and temperature patterns; surface water runoff; crop and animal breeds; new pests and diseases; and fertilization programs[1].

Changing agricultural practices, such as monocropping, which has replaced traditional methods of growing multiple crops on a piece of land, results in a loss in soil productivity and resultant soil degradation. This is enhanced through the increased use of chemical inputs, facilitating a vicious cycle whereby with each harvest, more chemical fertilizers and synthetic pesticides are required. South Africa already faces declining soil quality and generally, low organic matter levels[2]. Small-scale and household farmers are constrained by poor infrastructure and logistics. Opportunities to address these challenges are often constrained by the lack of access to modern technologies that can cheaply and easily revolutionize the sector. These include technologies like precision-farming, mobile or digital platforms, vertical farming, anaerobic bio-digesters or agri-processing options

Food losses and waste in South Africa are a growing reality, estimated to be in the order of 10.3 million tonnes 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 national GDP[3].

Continuing to follow a resource intensive, linear 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[4]. When applied to the agriculture sector, the circular economy principles of designing out waste, closing resource loops; and regenerating natural systems, provide a framework for South Africa to address food security[5]:

- **Design out waste**, e.g., precision farming; peri-urban and urban farming (bringing food production and consumption closer); the sharing economy
- **Keep materials in use**, e.g., returning nutrients to the agricultural system; biorefinery; value-add of waste products
- **Regenerate natural systems**, e.g., crop rotation; intercropping; mixed farming, reduced or zero till

'*Circular agriculture*' centres 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. The circular economy 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. If practiced on a wide scale, circular agriculture can reduce resource requirements (e.g. water, energy), land-use, chemical fertilizers, synthetic pesticides, GHG emissions, and ultimately the ecological footprint of agriculture.

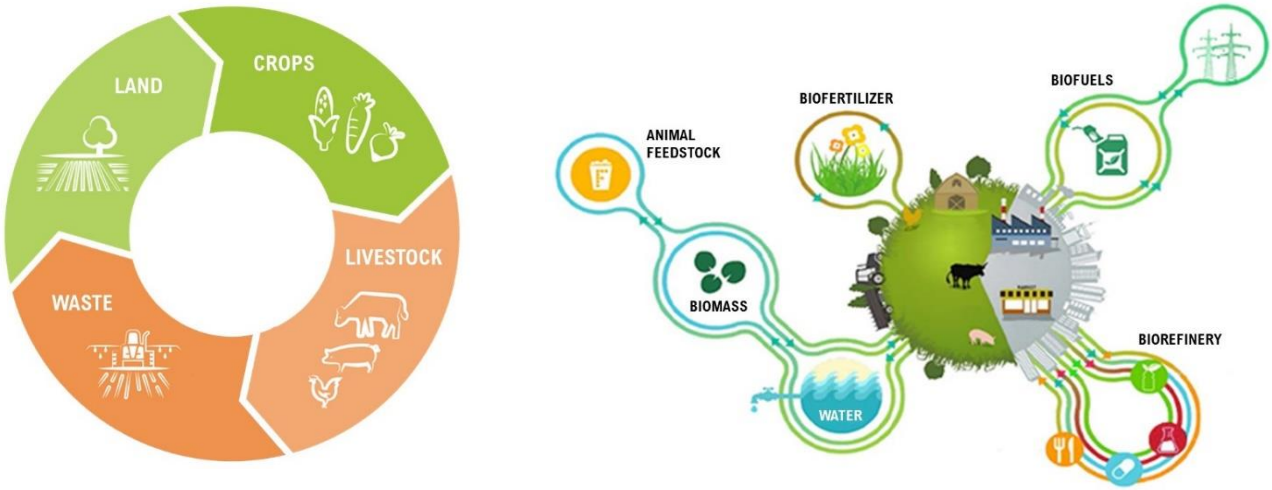


**Figure 1**. Circular agriculture and the valorization of waste from the agri-food sector (adapted from WUR[6] and AgrocCycle[7])

### The South African agricultural sector

South Africa is a major producer and exporter of agricultural products. The diversified agricultural sector produces a wide variety of agricultural commodities and is driven by both large-scale commercial farmers with sophisticated harvesting, storage and processing systems, and small-scale family farms practicing subsistence farming. Food production and retail is dominated by large corporations and large supermarket chains respectively[8]. The sector contributes 3% to South Africa's GDP. In 2019, the total income earned in agriculture and related services was R351,4 billion, with animals and animal products' generating the largest sales (R153,1 billion), followed by 'horticultural crops and products' (R86,3 billion) and 'field crops' (R61,9 billion)[9]. In 2021, the agricultural sector rebounded sharply (6.2% vs -0.1%) due to increased production of field crops, horticulture and animal products. The sector is projected to register a Compound Annual Growth Rate (CAGR) of 4.2% during the period, 2021-2026[10]. In 2019, the sector employed 5.0% of South Africa's working population which equates to 768,171 workers[9]. While the sector is a labour intensive one, employment in agriculture has declined every decade since the 1970s[11].

Land used for commercial agriculture is 46,4 million hectares, which represents 37,9% of the total land area of South Africa[12]. The sector is resource intense on water, energy, inorganic fertilizers, and synthetic pesticides to improve yields. Agriculture accounts for 61% of South Africa's water allocation (*See CSIR Water Briefing Note*) with all large irrigation schemes supplied from storage dams. As a result of high conveyance losses, a significant proportion of this water does not reach farmers[13]. Consequently, there is a need to improve crop water requirements and associated irrigation scheduling in order to improve water productivity in the sector[14]. Energy drives agricultural activities, with agriculture accounting for 6% of South Africa's energy demand in 2016 (*See CSIR Energy Briefing Note*). The agriculture sector has a high demand for liquid fuels, accounting for 87% of its energy demand, followed by electricity at 13%[15]. The energy needs are mostly in farming machinery, and the transportation of agricultural raw materials, feeds, intermediary and finished products from farms to various markets. In 2018, chemical fertilizer consumption for South Africa was 72.8 kg/hectare compared to a sub-Saharan average of 17 kg/hectare[16].

South Africa has a rich policy landscape applicable to agriculture and agro-processsing. The Agricultural Policy of 1998, Section 4 focusses on the conservation of agricultural resources. A number of other policies, including waste policies, have potential relevance in driving a more circular agriculture sector. The White Paper on Science, Technology and Innovation recognizes the circular economy as a new growth area for South Africa, with the need to modernize and strengthen productive sectors such as agriculture. The dtic and line departments are developing several sector master plans to support South Africa's industrialisation efforts. Relevant plans have been developed for agriculture and agro-processing, and the forestry, poultry, and sugar sub-sectors. While these plans focus on economic development, many already hint to circular economy principles.

### Opportunities for greater circularity in agricultural systems

Circular economy opportunities in the agriculture sector are briefly highlighted, aligned with the three circular economy principles:

#### *Design out waste and pollution*

Precision farming has shown good potential in increasing the efficiency of conventional agricultural systems when combined with regenerative practices. The use of agricultural IT, remote sensing and real-time environmental data can optimise crop yields, increasing farmer income, while reducing environmental externalities. Precision agriculture provides enhanced control over inputs like energy, water, fertilisers and agrochemicals by delivering the right amount, at the right time, and at the right place, using geo-spatial variability in soils, micro-climate and other relevant husbandry parameters. Precision farming promotes good stewardship of the land for future generations and preserves its potential for multiple uses. An example is *Fruitlook*[17], where the Western Cape Department of Agriculture (WCDoA) is offering a state-of-the-art information technology

that helps deciduous fruit and grape farmers to be water efficient and climate smart. *FruitLook* allows these farmers to improve their water use efficiency using information from spatial data derived from remote sensing, which provides semi-real-time information on crop growth, evapo-transpiration deficits, and nitrogen status for irrigation blocks. This technology is currently limited to orchards and vineyards in the Western Cape's key growing areas.

Agricultural mechanization is a key driver of efficient farming systems. Business models for mechanisation hire services through the sharing economy, can facilitate greater access to advanced equipment, supporting improved productivity – particularly for small-scale farmers. Globally, the agricultural sector is seeing a shift from an owner-focused value proposition to a customer-centered one, through product-as-service. This has now extended to farmer group service providers. In this model, a group of farmers pool their resources and increase access to agricultural mechanization services. Services cover all operations in the agricultural value chain, from tillage to post-harvest activities, processing, and transport. The benefit is that the machinery is available to the farmer at lower prices; with optimization of heavy machinery (e.g., tractor) use; machinery is driven or controlled by an expert; timely access to the equipment; access by vulnerable groups including women; and flexibility for payment.

Emerging technology innovations have the potential to enable greater circularity in South Africa's food systems, for example by increasing supply chain efficiency, boosting farm productivity, and improving citizen's nutrition. Examples include:

- Chemical leasing which is centred 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.
- Mobile or digital platforms that create better connections between producers and consumers.
- Digitally enabled business models to facilitate equipment sharing or on-demand services.
- Packaging technologies and agro-processing technologies to reduce post-harvest and food losses.

*Keep products and materials in use*

There are substantial food losses and wastes in supply chains, from farm to table. This is largely due to the lack of required market infrastructure; lack of safe transport; improper handling and packaging; lack of standardization and grading; under-developed cold chains; and improper processing. South Africa has committed to halve per capita food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses by 2030, in line with the Sustainable Development Goals. The Consumer Goods Council of South Africa (CGCSA) has given effect to this through a food loss and waste voluntary agreement[18]. Where food losses and waste cannot be prevented, they can be productively recycled back into the economy through various technology routes, including composting to organic manure, or anaerobic digestion to produce bio-energy. South Africa's chemical fertiliser consumption is more than three times higher than the sub-Saharan average[19]. An opportunity exists to increase the use of organic fertilisers, so that nutrient loops are closed and the need for mineral fertilisers is reduced. The application of organic fertilisers will also help to rebuild the topsoil and soil holding capacity of agricultural lands. For centuries, 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. Organic waste streams can also be used to recover high-value materials through biorefinery technologies, including various platform chemicals[20]. The Biorefinery Industry Development Facility (BIDF), hosted by the CSIR, is working with several industries across the agriculture and agro-processing sectors to find appropriate, high-value solutions for various organic waste streams traditionally destined for disposal to land[21]. When optimally implemented, these pathways can result in full value chain processing of waste biomass. This obviates the need to dispose of waste through landfilling, burning, stockpiling, or discharge to sea, and with it mitigating the generation of GHG emissions.

South Africa already faces challenges in terms of food security; water scarcity; a decrease in arable land; high population growth and rapid urbanisation. The adoption, in urban and peri-urban settings, of sustainable farming systems, such as vertical agriculture, hydroponics, aquaculture, aquafeed from agricultural waste, and aquaponics, could result in several advantages and benefits:

- The production of fresh, healthy, nutritious, and pest-free food all year-round – where production is not dependent on the weather.
- Significant reduction in the use of water – vertical farming uses 96% less water and recycles the water.
- The use of renewable energy.
- Efficient use of land and production can take place in urban, industrial, and rural settings close to consumers and market thus reducing transport costs, and consequently carbon emissions.
- Higher yields per cultivated hectare and no loss of harvest because of adverse weather conditions, drought, or pests.
- Longer shelf life of produce and reduction in input costs.

The use of treated wastewater, rain water harvesting and return-flow systems where drainage and surplus irrigation are channeled back, are integral elements of circular agriculture.

Industrial symbiosis also provides opportunities for keeping materials in use. Through the intentional clustering of mutually beneficial resource-converting industries, by-products and waste materials from one company can be used as input into another. UNIDO is supporting the establishment of integrated agro-industrial parks (IAIP) throughout Africa. The objectives of IAIPs are to create a better environment for increased investment in agro-food and allied sectors; drive the structural transformation of the economy; and reduce rural poverty. Based

on the agri-business value chain concept, a rigorous base of specialized services are deployed targeting the weaker links of the chain including: agricultural mechanization, modern processing technologies, packaging of perishable products, the promotion of food safety in the processing and regulatory environment; and interventions to improve competitiveness and productivity. The IAIP is a geographic cluster of independent companies grouped together to provide economies-of-scale and add value to the output of the agricultural sector, thereby improving competitiveness and productivity. This includes providing shared services for the reuse and beneficiation of waste[22].

*Regenerate natural systems*

Regenerative agriculture, such as indigenous knowledge-based agriculture, is not new in South Africa. Regenerative agriculture aims to preserve the integrity of the natural system. Traditional practices such as crop rotation; inter-cropping; mixed farming (combining livestock and crop production to create additional nutrient loops); minimum tillage; agroforestry (tree planting in combination with crops or pastures), ecological aquaculture; food waste application in gardens; and cover cropping can support circular economy goals towards an optimised agricultural system. This approach can facilitate a wide set of long-term benefits including nutrition; preservation of genetic biodiversity; carbon capture, soil protection; water conservation; lowering external inputs and improving the larger ecosystem as a whole. This is in stark contrast to linear agriculture's narrow focus on short-term productivity and yield gains through intensive farming practices and synthetic inputs – at the expense of long-term farm health and the environment. Effective regenerative agriculture approaches need to encompass aspects such as: embracing crop biodiversity, leveraging traditional agro-ecological knowledge, as well as appropriate technology and scientific knowledge on eco-systems, soil health, nutrition and resilience – whilst being adaptive to the context and geography[23].

It is clear that the principles of a circular economy are not new to the South African agriculture sector. Transitioning the sector from a linear to a circular one is a necessity to support food security and to unlock new economic opportunities. However, the sector requires the development and application of new knowledge, leading to innovative, technological, and sustainable processes, products, and services[24]. The circular economy has the potential to be scaled and fast-tracked through a number of global trends[25], many of which have direct bearing on the agriculture sector –

- Smart farming
- Sensor technology
- Information technology
- 3D and 4D printing
- Smart materials
- Robotics
- Autonomous micro-robots
- Bioinformatics
- Renewable energy
- Biorefinery and biofuels
- Genetics
- Synthetic biology
- Protein transition
- Food design
- Aquaculture
- Vertical agriculture
- Conservation technology
- Transport technology

## Conclusions

Agriculture is a highly resource intensive sector, with a demand on South Africa's energy and water systems for land preparation, seeding, irrigation and harvesting, amongst others. The water-energy-food nexus is fundamental to South Africa's economy, and any increase in demand in any one sector has knock-on effects on the others. Transitioning to a more circular agricultural system creates very real social, economic and environmental benefits for South Africa. These include improved food security; resilience; global competitiveness; economic development; job creation; decarbonising the sector; sustainable resource utilization; and sustainable food systems.

**Acknowledgements:** The authors acknowledge the funding from the Department of Science and Innovation through the CSIR's Parliamentary Grant.

## References

1. Johnson (2019). Farming in South Africa is under threat from climate change. Here's how [online]
2. Du Preez, C. et al. (2011). Land use and soil organic matter in South Africa [online]
3. Oelofse, S., *et al*. (2021). Increasing reliable, scientific data and information on food losses and waste in South Africa [online].
4. EMF (2016). Circular Economy in India: Rethinking growth for long-term prosperity [Online].
5. EMF (2017). Circular Economy in Detail [online]
6. WUR (2021). Circular agrofood system [online]
7. Agrocycle (2017). A blueprint and EU policy-forming protocol for the recycling and valorisation of agri-food waste [online]
8. Oelofse, S., *et al*. (2018). Household food waste disposal in South Africa: A case study of Johannesburg and Ekurhuleni. *S. Afr. J. Sci.,* 114(5/6)
9. StatsSA (2019). Agricultural survey (Preliminary) 2019 [online]
10. Mordor (n.d.). Agriculture in South Africa - Growth, Trends, Covid-19 Impact, and Forecasts (2021-2026) [online]
11. CDE (2019). Making South Africa more labour intensive [online]
12. StatsSA (2017). Census of Commercial Agriculture. Pretoria: Stats SA. Retrieved from Census of Commercial Agriculture.
13. UNEP (2009). Water sustainability of agribusiness activities in South Africa. *Chief Liquidity Series* 1,42-46 [online]
14. CSIR. (n.d.). Agricultural and forest water use and water management [online].
15. DoE (2019). The South African Energy Sector Report [online]
16. Knoema. (n.d.). Retrieved from World Data Atlas [online]
17. Western Cape Government. (n.d.). Case Study 1 Fruitlook [online].
18. CGCSA (2021). South Africa's Food Loss and Waste Voluntary Agreement: Implementation plan [online]
19. EC (2020). Circular economy in the Africa-EU Cooperation: Country Report for South Africa. Brussels: Trinomics.
20. DST (2016). Bio-based chemicals landscape of South Africa.
21. CSIR (n.d.). Biorefinery Industry Development Facility [online]
22. UNIDO (2019). Circular Economy and Agribusiness Development [online]
23. EMF (2021). Circular Economy in Africa: Examples and Opportunities - Food and Agriculture [Online].
24. Abad-Segura, E., *et al*. (2020). Sustainable management of digital transformation in higher education: Global research trends. *Sustainability*, 12(5), 2107.
25. FAO (2017) The future of food and Agriculture, Trends and challenges [online].
26. Footprints Africa (2020). The Circular Economy: Our Journey in Africa So Far [online]