MARKET ANALYSIS: DETERMINING THE EXTENT AND POTENTIAL OF A WATER-SMART AGRICULTURE MARKET IN SOUTH AFRICA

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Market Analysis: Determining the Extent and Potential of a Water-Smart Agriculture Market in South Africa

Report to the
Water Research Commission

by

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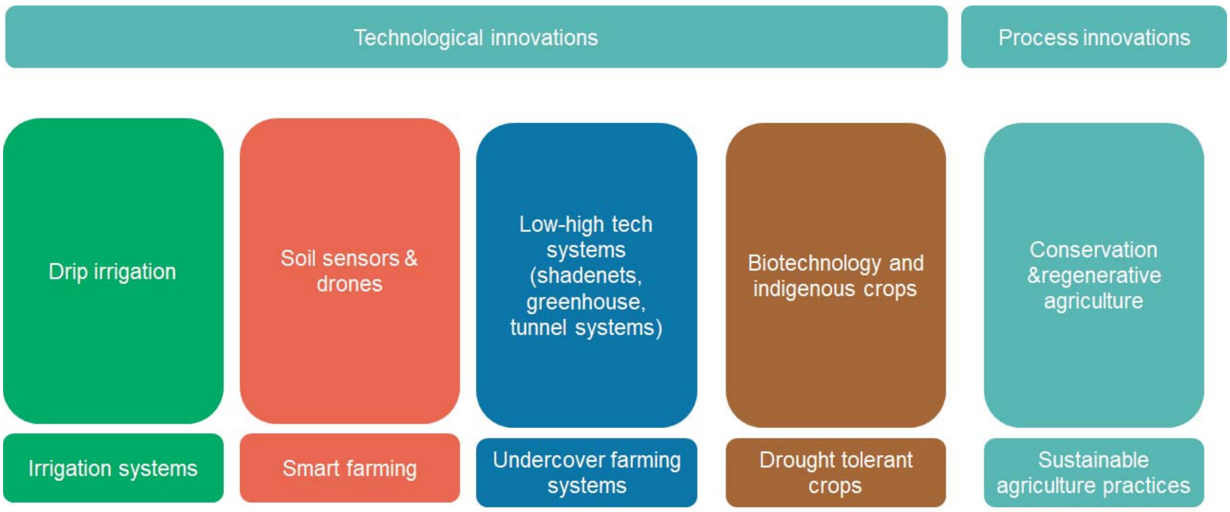
Executive Summary

In a water-stressed South Africa, conventional agricultural practices such as heavy irrigation, the use of synthetic chemical fertilisers, pesticides and herbicides, intensive tillage and monoculture, continue to exacerbate detrimental environmental effects and water constraints. Studies have shown that there is an increasing interest in agricultural innovation by investors in response to the state of water in South Africa. Reducing pollution and soil degradation, improved information systems and rolling out of water efficiency technologies for irrigation are emerging as key opportunities for sustainable farming. A number of innovations (processes and technologies) have been developed that could lend to the emergence of a Water Smart Agriculture (WSA) market. However, a consolidated view on the type, readiness, size and potential of WSA innovations for the South African market is still unclear.

This market research was developed to explore WSA innovations that demonstrate a prospective South African market and identify opportunities for industrial and socio-economic development. The research further assessed and determined the size and potential market for WSA innovations. The findings of the market analysis are based on insights from stakeholder interviews, a survey sent out to technology providers and an extensive literature review of WSA innovations.

WSA innovations have been defined as those technologies and practices that contribute to the principles of climate smart agriculture as defined by the Food and Agriculture Organisation of the United Nations (i.e. increased productivity and incomes, increased resilience and reduced greenhouse gas emissions) but in the context of this study aim to improve water use efficiency and productivity. The key WSA innovations that have been identified in this market analysis and hold potential for the South African agriculture sector are detailed in the figure below.



WSA innovation clusters and technologies

The identified WSA innovations are driven by a range of economic, environmental, social and regulatory factors. A few of these highlighted in the report are summarised below.

- **Rising input costs.** The rising cost of inputs such as energy and fertilisers drive the need for producers to become more efficient in their agricultural activities. On irrigated farms, energy costs are high because of the energy used to pump irrigation water. With rising electricity costs in South Africa, investing in water-efficient technology is important for the financial sustainability of farms.
- **Scarce natural resources.** Scarce natural resources, particularly productive land and water, limit agricultural production, which drives the need for farmers to increase their water use efficiency. Low and erratic rainfall, as well as limited arable land makes water the most limiting factor in agricultural production in South Africa.
- **Population growth**. The expected population growth will increase the demand for water, food and energy, resulting in increased competition for natural resources. Given the scarcity of natural resources, the increasing demand will drive a need for sustainable and efficient ways to intensively produce food. Additionally, consumer preferences are evolving and include more focus on health and wellness. While the traditional drivers for food purchases such as price, convenience, and taste still hold, there is a shift towards a wellness mind-set and interest in the transparency of food products. This drives a need for increased monitoring of farm operations and practices to provide access to the relevant information.
- **Climate change.** Variability in the climatic conditions has severe consequences on the production and quality of food resulting in negative economic consequences. The effects of climate change have been felt across the country in the form of drought conditions, severe floods, and wildfires. It is anticipated that these impacts will continue in the long-term. The changes in the climate will have ramifications on the water demand for crops grown in both irrigated and rain-fed systems. The variations in seasonal rainfall and increased temperatures will increase the demand for water for evapotranspiration on crops and thus driving a need for efficient water systems.
- **Water metering.** All irrigation farmers are now required to accurately meter their water usage and report it to the Department of Human Settlements, Water and Sanitation. This necessitates increased monitoring and measuring of water-use on farms. In addition, this measure has shown to improve the management of water resources due to the increased awareness of water usage.

A summary analysis of the different WSA innovations including the market readiness, market size estimates, drivers, market growth potential and barriers is shown in the table below.

Summary analysis of WSA innovations

Innovation cluster	Technology	Market readiness[1]	Market size estimates	Market growth potential[2]	Market drivers	Market barriers	
						Commercial farmers	**Smallholder farmers**
Irrigation systems	Surface drip irrigation	H	The market size for surface drip irrigation systems was estimated at R1.48 billion per year	L-M	Policy related drivers (water policies and revitalisation of irrigation schemes)	• High maintenance costs • High investment costs • Limited technical knowledge and skills • Long return of investment (~7 years)	• Affordability of technology too high. • Poor performance of irrigation schemes due to poor infrastructure maintenance. • Lack of institutional support • Lack of extension and training.
	Sub-surface drip irrigation	H	The market size for sub-surface drip irrigation systems was estimated at R244,90 million per year	L-M			
	Low-flow drip irrigation	M	The market size for low-flow drip irrigation systems was estimated at R17.49 million per year	M-H			
Smart farming	Remote sensing services	M-H	The potential market was estimated at R671	H	Increasing farm operations International food standards	• Internet connectivity • Skills and knowledge	• There are barriers linked to affordability of innovations, access to inputs and lack of information.

[1] The market readiness was defined according to Florin Paun (2012) which integrates demand readiness level scale and technology readiness. The stage of development of the technology was ranked as follows: high (H) = standard technology and readily adopted; medium (M) = gaining traction; low (L) = recently commercialised.
[2] Market growth potential ranked as high (H), medium (M) or low (L) based on market trends and drivers of innovation.

Innovation cluster	Technology	Market readiness[1]	Market size estimates	Market growth potential[2]	Market drivers	Market barriers	
						Commercial farmers	Smallholder farmers
	Sensor technology	M	billion (2017-2026) for digital technologies in the agriculture sector Market size for remote sensing services was estimated at R459 million Market size for soil sensors was estimated at R 2.89 billion The drone industry market was estimated at R2 billion (2017)	M-H	and regulations Affordable technology Water scarcity	gap • Cost of purchasing new technology and time invested in setting up farms • Value of information collected to farmers • Lack of awareness on type of technology available and associated benefits	• There is reliance on extension officers to provide support on farm management and often there are limited number of officers and resources, which limits farmers' access to information. • Poor digital literacy • Lack of awareness on type of technology available and associated benefits
	Drones	M		M			
Undercover farming systems	Low and medium tech systems (i.e. shade nets and tunnels)	H	The estimated market size is R2.4 billion	M	Urbanisation Climate change and water scarcity Consumer preferences	• High initial investment costs especially for high-tech systems • Electricity costs due to high energy requirement from indoor farming systems • Access to land and suitable space • Limited technical skills and knowledge	• Access to markets. In cases where tunnel farms have been implemented at household level or at a small-scale, a key barrier noted was accessing markets. • Limited of technical skills and knowledge
	High-tech systems (i.e. greenhouses with soilless growing mediums)	M-H	The estimated market size is R11.78 billion	H			
Sustainable practices	No-till machinery	H	The estimated market size for no-till machinery is R4.48 billion	H	Financial benefits due to reduced operating costs Financial instruments from	• Lack of awareness of benefits of conservation	• Lack of start-up capital to purchase CA equipment • Lack of knowledge and training on

Innovation cluster	Technology	Market readiness[1]	Market size estimates	Market growth potential[2]	Market drivers	Market barriers	
						Commercial farmers	**Smallholder farmers**
	Biofertilisers	L-M	R410 million (2017)	M	Banking Association of South Africa and Land Bank credit line ear-marked for climate smart agriculture incentivise adoption of sustainable practices International policy regulations on stricter measures for use of chemical fertiliser promote the use of bio-based and organic fertilisers	agriculture • The long period for the benefits of CA to materialise has been noted as a barrier to farmers. It takes about five to seven years for the transition to CA on farms and this period could have negative implications on yields and profit margins. • Lack of suitable planters for local conditions. • Lack of knowledge about implementing CA principles • High cost of imported equipment due to associated maintenance costs	conservation agriculture practices and the associated benefits • Lack of access to equipment tailored to farm operations • Lack of an enabling policy environment • Limited access to markets discourage farmers to meaningfully adopt CA practices
Drought tolerant crops	Biotech crops	L	There are currently no commercially available drought-tolerant crops, however, the economic gains from biotech crops (insect and herbicide tolerant) in South Africa have been estimated to be over R2.91 billion	L-M	The drivers for drought tolerant crops are mainly regulatory. The policies that could drive the uptake of drought tolerant crops include the National bioeconomy strategy which makes mention of unlocking opportunities for indigenous products and expansion of research for GM crops	• Crop breeding represents a long term investment, in terms of both time and money. Although recent advances in maize breeding have reduced the time taken to develop new varieties, it still requires a minimum of six years • Global markets are inaccessible due to weak networks and policy instruments. • High regulatory barriers for product approval. • Social perceptions of underutilised crops as they considered as being "low status", "backward" or "old fashioned" or "poor man's" crops. • Insufficiently trained human resources who possess the technical aspects of producing underutilised crops.	
	Underutilised indigenous	L	The market size for the bioprospecting	M-H			

Innovation cluster	Technology	Market readiness [1]	Market size estimates	Market growth potential [2]	Market drivers	Market barriers	
						Commercial farmers	Smallholder farmers
	crops		industry was estimated at R2.5 billion per year. This was based on the total revenues generated in the primary and processing of indigenous resources.				

Summary of WSA innovations market opportunities

The market opportunity and demand analysis highlighted key opportunities from all the innovations in terms of the market growth potential. These are summarised below.

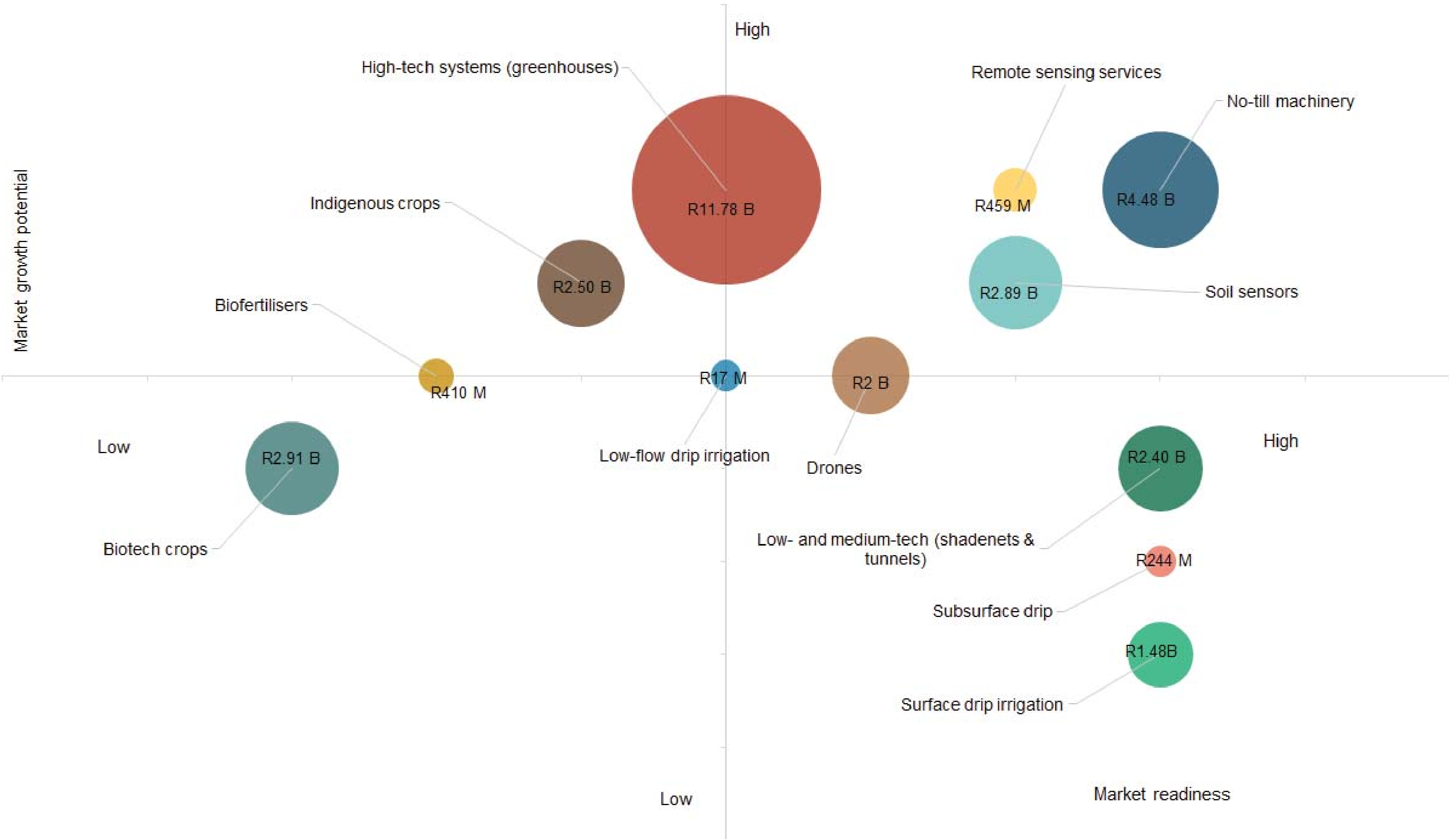
- A large number of WSA innovations have been observed in medium- to large-scale commercial farms, mainly due to significant economies of scale. The adoption of WSA technologies is still relatively low among smallholder and emerging farms. This presents an opportunity for WSA innovations to be disseminated to this market segment. However, the innovations would need to be fit for purpose and account for the context in which the farms operate.
- The market growth potential for WSA innovations is likely to be a factor of a growing demand for high value crops and increasing area under production. Therefore, high growth crops such as citrus, avocados, macadamia nuts, berries, oilseeds and grains are attractive for WSA innovations. In addition, the growing niche market for crops such as mushrooms, micro-greens, or leafy greens driven by consumer preferences for fresh and plant-based foods, have the potential for increased growth in WSA innovations, especially high-tech undercover farming systems.
- High-tech undercover farming systems and no-till machinery currently present the highest market size estimate. This is mainly due to the high capital costs associated with the technologies which limits their uptake. In addition, most of the equipment and technologies is imported which has associated administrative costs to maintain the technologies. Therefore, there is an opportunity for local manufacturers to tap into this market and develop affordable and accessible equipment.
- The emerging and disruptive nature of smart farming technologies shows a high market growth potential, especially remote sensing services. Remote sensing services provide an opportunity for farms with existing infrastructure (hardware) to improve decision making processes and farm management. Whereas, for farms with no existing infrastructure, this service becomes an attractive add-on. Moreover, the interest in a centralized database for better farm management and decision making, becomes attractive for remote sensing services.
- Indigenous crops also hold a high market growth potential due to the growing demand for natural products coupled with opportunities presented in the agro-processing sector. These crops are currently cultivated in South Africa, however, most are grown for subsistence or traditional medicines. Thus, the growth of the crops depends on the mechanisms that are implemented to remove the barriers that hinder their wide spread adoption.
- The African Continental Free Trade Agreement (AFCTA) provides opportunities for increased competitiveness in the agriculture sector. The removal of tariffs on 90% of the all goods traded will open up markets for agricultural products, with increased market access to countries like Nigeria, Angola and Senegal presenting opportunities for increased production of apples, oranges and wine

grapes. This export market demand presents opportunities to leverage off WSA innovations for increased competitiveness.

- Stringent international climate strategies and ambitions (i.e. European Green deal and chemical fertilizer bans in countries like China and India) could further drive the uptake of WSA innovations, especially among export farmers.
- Nationally, regulatory instruments such as the carbon tax act which will include the agriculture sector in 2022 could drive the uptake of cleaner and efficient solutions such as biostimulants and regenerative agriculture.
- The closure of mines in Mpumalanga and current projects initiated to rehabilitate the mining land for agricultural production, present an opportunity for a transition to sustainable agricultural production. This creates an opportunity for integration of WSA innovations on this land.

Given these opportunities, a summary of the market opportunity map[3] is shown below.

[3] The bubble size represents the market size estimate, the y-axis shows the market growth potential and the x-axis shows the market readiness of the different technologies.



Market opportunity map for WSA innovations

While the WSA innovations hold potential for the South African market, there are significant barriers that hinder their uptake. The major barriers to the uptake and diffusion of WSA innovations are underpinned by ineffective agricultural innovation systems or lack thereof. The major barriers to the uptake of WSA innovations vary from the demand and supply side actors. The barriers to the uptake of WSA innovations that have been encountered by demand and supply side actors and proposed interventions are noted in below.

Demand-side barriers and interventions to the uptake of WSA innovations

Barrier	Description	Proposed intervention
High cost of WSA technologies	Certain WSA innovations require a significant upfront investment that is not often possible for smaller farmers. In addition, the return on investment may take some time to realize, thereby reducing the likelihood that this outlay will be made, particularly in sectors that have low profit margins or are in decline.	Preferential financing should be offered by financial institutions to farmers who invest in WSA innovations. Notably, the term of the debt could be adjusted to allow for the maturation of the benefits from these investments in order to promote their uptake, whilst improving their financial resilience. Shift in mindset towards value proposition thinking and better understanding of the business case. Promotion of incentive based financing mechanisms, where known WSA innovation off-takers are incentivised for adoption. In doing so, the early adopters can promote the innovation within their networks. There is a need for more impact investors to de-risk loans offered from local commercial banks. Development of OPEX-based models or leasing options for agricultural equipment (e.g. Axl app from AFGRI)
Incremental value of innovation to farmer	Farming enterprises are faced with so many challenges that the decision to adopt a new technology needs to be aligned with their farm priorities and cash flow reserves.	Government support programmes to incentivise adoption of water smart technologies. Piloting the technology through farmer associations and irrigation boards to share with their members. Aligning and tailoring the value proposition of the innovation between the innovator and end-

Barrier	Description	Proposed intervention
		user and taking into account the different contexts in which farms operate. This can take form of demand or user-led research.
Lack of awareness	There is a lack of awareness around the benefits, capabilities and business cases for new technology. The linkages between water use efficiency, energy efficiency, nutrient optimisation and land productivity is poorly understood, yet is highly relevant in understanding the business case behind some of the WSA innovations.	Developing tools and training modules that highlight water risks to farmers and support farm level water balance decision-making. Utilising existing platforms from agricultural associations and networks to disseminate information on WSA innovations through discussion platforms such as smart water indaba
Complexity of innovation	The user-friendliness of a technology is a key factor that determines whether farmers will adopt a technology. If a technology is too complex and costs a lot of time to apply, farmers are unlikely to adopt the technology.	Initiating mentorship programmes where emerging farmers are guided and supported by established commercial farmers. Targeted training on the different WSA technologies. Webinars, symposiums and workshops that are frequent and freely available to all farming types.
Limited technical skills and knowledge	There is a lack of local skills and knowledge for many WSA innovations, especially technical skills in the development of farming technologies. This can result in sub-optimal operation of the WSA innovations, thereby undermining their effectiveness, while also limiting the roll-out of these innovations.	
Price of water	The low cost of water for farmers undermines the business case for investment in WSA innovations. The cost of irrigation water varies across the country but it is considered to be very low and is subsidised by other users. As noted, the driver for WSA innovation is more likely to be energy costs, not water. In cases where energy and water usage are not linked (particularly dryland agriculture), the low or zero cost of water may reduce the incentive for efficiency investments.	Linking water use thresholds into finance instruments to incentivise reduced consumption and increased re-use.

Supply-side barriers and interventions to the diffusion of WSA innovations

Barrier	Description	Proposed intervention
Accessing finance for full commercialization of innovations	Businesses interviewed noted that although there might be funding for technology development and commercialisation, funding or support for business-related expenses is often not accounted for, which limits operations and growth of the business.	Life-cycle support for early stage businesses. More long-term support from all players is needed for early stage businesses due to the time it takes (estimated at a minimum of 5 years and beyond) to commercialise WSA technologies. Moreover, the role of government has been highlighted as a key enabler for greater diffusion of innovations. This has been alluded to in the form of removing regulatory barriers and creating an enabling environment for increased adoption
Limited access to markets	There are several technologies that have been introduced but have failed to be adopted by famers. Mainly because the technology did not align with the priorities of the farms. Additionally, if it is a new technology that is not widely adopted it becomes a challenge to convince farmers to adopt it unless leading farmers within their network have already implemented it and are reaping the benefits.	Access to innovative marketing and piloting platforms that can reach both smallholder and commercial farmers have been as a key area to increased uptake of WSA innovations. A different model of agricultural extension for marketing innovations to smallholder farmers
Lack of networking and collaborating platforms	Lack of networking platforms for smoother collaboration with players operating in this space (such as farmers, funders, incubators, regulatory bodies, or research institutions). A challenge highlighted is that start-up companies operate with a range of different institutions and stakeholders with different governing mandates. The various processes and systems that start-up companies have to adhere to has cost implications, which for a business with limited cash-flow becomes unsustainable.	Increased collaboration among actors. The linkages to the different actors along the WSA innovation value chain are critical to ensuring the path to commercialisation of WSA innovations. This could take the form of a networking platform which could provide information on the players that add value in the agriculture sector and provide opportunities for increased collaboration.
Stringent licensing and compliance processes	The regulatory environment is unfriendly for the diffusion of technology, especially for small businesses. Most water smart agriculture innovators have to adhere to compliance processes and protocols which often take a long time or have delays and result	Capacity building and support to policy makers to improve productivity and efficiency.

Barrier	Description	Proposed intervention
	in administrative burden and costs, which limits the scaling and diffusion of WSA innovations.	
Competition with imported low-cost technologies	A key challenge noted by local equipment manufacturers is that they struggle to convince farmers from purchasing cheaper and imported machinery, which hinders and limits the uptake of locally produced equipment. Thus, this creates a need for greater support systems for local innovations for manufacturers to become more price competitive.	Increased government support for water smart agricultural innovations through tax incentives or rebates. The media has a role to play in promoting local brands and changing the perception around local products.

Recommendations

The barriers highlighted in the report largely hinder the wide-spread adoption of WSA innovations. Therefore, the recommended next steps for increased diffusion and uptake of water smart agricultural innovations are detailed below. These can be implemented by key players that operate within the water and agricultural ecosystem and are underpinned by a **collective effort** of the different role players.

1. Development of innovative financing models

Based on the insights gathered, it is clear that finance is a major barrier to the uptake and diffusion of WSA innovations. Therefore, there is a need for innovative financing models to be implemented and incentive based finance systems to be in place. Moreover, it is crucial to re-think the business models and support services of the different innovations and the degree to which they add value to the different farming types (smallholder to established commercial farms). Proposed actions to achieve these include:

- Formulating partnerships between innovators and financial institutions to develop innovative financing options for agricultural innovations (examples could include innovative leasing and rental options for farms with limited cash flows). This partnership can be formulated through Development finance institutions (DFIs) or commercial banks and institutions that represent WSA innovators. These institutions can include the South African Irrigation Institute (SABI), AgriSA, Agricultural Business Chamber or the South African Agricultural Machinery Association (SAMA) or innovation entities (i.e. Technology innovation agency or Department of Science and Innovation).
- Research to further understand effective financial and business model scenarios to diffuse WSA innovations to the different farm types, especially emerging and smallholder farms.
- Establishing more blended finance options similar to the recent Agri-industrial fund between the Industrial Development Corporation (IDC) and the Department of Agriculture Land Reform and Rural Development (DALRRD) to de-risk loans for WSA innovations.

2. Increased awareness and value of innovations to farmers

While there is some uptake of WSA innovations in South Africa, some of these are not tailored to address the needs of the farmers. This is partly due to limited communication and collaboration between innovators and end-users. Thus, innovators should work collaboratively with farmers to align the innovations to the needs and values of the famers. This collaboration can further provide a platform to increase awareness on the benefits of the different innovations. The key actions to implement these are:

- WSA innovation entities could leverage off existing platforms from producer associations such as farmer information days, auctions and exhibitions to establish discussion and piloting platforms to effectively develop appropriate solutions that meet the needs of the farmers.

- Scaling decision support tools that highlight water risks to farmers and provide support on farm level water balance decision-making. Examples of these have been developed or are being developed by a range of institutions such as the Council for Scientific and Industrial Research (CSIR) and several university institutions through support from the Water Research Commission (WRC).

3. Increased training and mentorship opportunities

Limited skills and knowledge related to the use of the technologies is another barrier to the uptake of WSA innovations. Frequent training and accessible platforms are needed to increase the uptake of innovations. Proposed actions to achieve this include:

- Establishing platforms to provide training and awareness of the different innovations (i.e. seminars, workshops or freely accessible online tools). Online tools and seminars could be hosted and developed by institutions such as the WRC.
- Integrating WSA innovations into incubation and agricultural training programmes. The trainings can be aligned to skills programmes such as Agriculture Sector Education Training Authority (AgriSETA) or Energy & Water Sector Education Training Authority (EWSETA).
- Developing mentorship programmes on WSA innovations that facilitates knowledge exchange between established commercial farms, emerging and smallholder farms. The mentorship programmes can be facilitated by producer associations or incubation programmes that support agribusinesses.

4. Increased government support

Market entry and access is a key challenge that most businesses face when trying to scale their innovations and this is partly due to an unfriendly regulatory environment. Thus, the government has a role to play in providing an enabling environment for increased adoption of WSA innovations. Proposed actions are:

- Incentives for adoption and promotion of WSA innovations such as tax rebates or incentives.
- Strengthening collaboration between relevant government departments (such as Department of Agriculture Land Reform and Rural Development, Department of Water Affairs and Sanitation, Department of Science and Innovation, Department of Trade Industry and Competition).
- Incorporating water smart agriculture into government strategies and policies (i.e. Agriculture and agro-processing masterplan).

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Table of Contents

List of Acronyms

AATF	African Agricultural Technology Foundation
AgriSETA	Agriculture Sector Education Training Authority
BFAP	Bureau for Food and Agricultural Policy
CA	Conservation Agriculture
CEA	Controlled Environment Agriculture
CSIR	Council for Scientific and Industrial Research
DAFF	Department of Agriculture Forestry and Fisheries
DALRRD	Department of Agriculture Land Reform and Rural Development
DEFF	Department of Environment Forestry and Fisheries
DWS	Department of Water and Sanitation
EWSETA	Energy & Water Sector Education Training Authority
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GMO	Genetically Modified Organisms
ICT	Information and Communications Technology
IDB	Inter-American Development Bank
IDTT	Industrial Development Think Tank
IoT	Internet of Things
IRR	Internal Rate of Return
ISAAA	International Service for the Acquisition of Agri-biotech Applications
LED	Light Emitting Diode
NDP	National Development Plan
NPV	Net Present Value
PMG	Parliamentary Monitoring Group
RA	Regenerative Agriculture
SAMA	South African Agricultural Machinery Association
SAMAC	Macadamias South Africa
SMME	Small Medium Micro Enterprises
SPIN	Small Plot Intensive Farming
SPIS	Solar Powered Irrigation Systems
StatsSA	Statistics South Africa
UAV	Unmanned Aerial Vehicle
UF	Undercover Farming
VAT	Value Added Tax
VRT	Variable Rate Technology
WCDoA	Western Cape Department of Agriculture
WEMA	Water Efficient Maize for Africa
WRC	Water Research Commission
WSA	Water Smart Agriculture
WWF	World Wide Fund

List of Figures

List of Tables

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1. Introduction

1.1. Context

The agricultural sector in South Africa contributes approximately 3% to South Africa's Gross Domestic Product (GDP) and plays a significant role for employment, job creation and earning foreign exchange. The sector is dependent on approximately 63% of the countries water allocation. Variable rainfall patterns not only affects dam and surface water but also groundwater recharge. Rising temperatures, climate change and droughts have serious long-term consequences for South Africa's food security. When coupled with the growing impacts on the quality of our water sources due to e.g. pollution from agricultural run-off, South Africa requires a focused approach to shifting the sector to more sustainable practices.

In a water stressed South Africa, conventional agricultural practices such as heavy irrigation, the use of synthetic chemical fertilizers, pesticides and herbicides, intensive tillage and monoculture, continue to exacerbate detrimental environmental effects and water constraints in South Africa. Studies have shown that there is an increasing interest in agricultural innovation by investors in response to the state of water in South Africa. Reducing pollution and soil degradation, improved information systems and rolling out of water efficiency technologies for irrigation are emerging as key opportunities for sustainable farming. There are numerous farmers embedding sustainable and water efficient practices and technologies into their operations, particularly in the large commercial fruit and wine sectors, typically producing high-value export outputs. These producers are some of the most efficient water users in South Africa and even globally. South Africa however produces a wide range of agricultural commodities across different farm groups and geographical areas and thus the potential size and focus of a Water Smart Agriculture (WSA) market in South Africa requires crucial consideration.

1.2. Purpose and scope

A number of innovations (processes and technologies) have been developed that could lend to the emergence of a WSA market. However, a consolidated view on the type and readiness of innovations for market are still unclear. Thus, the objectives of this study are to:

- Assess and determine the size and potential market for WSA innovations
- segment and categorise WSA market opportunities, highlighting key drivers, barriers and enablers across policy, economic, social, environmental and legal/regulatory (PESTEL) contexts within South Africa,
- produce a comprehensive list of WSA innovations (technology and process) that demonstrate a prospective South African market and opportunities for industrial and socio-economic development, and aid in prioritising WSA interventions,
- provide insights into pathways for diffusion on WSA innovation and highlight new areas of research, innovation and impact,
- provide recommendations to advise diffusion and adoption on WSA innovations.

Although agriculture in South Africa broadly considers the forestry and fisheries industry, this study focused on identifying innovations applicable to the primary agricultural sector in crop and livestock production.

1.3. Methodology

The market analysis comprised of primary and secondary research to estimate market sizes and trends and illustrated in Figure 1 below.

Figure 1: Methodology overview

1.3.1. Primary research

Primary research consisted of stakeholder interviews, and surveys, specifically:

- Industry experts were selected based on various technologies and sub-sectors identified, and a purposive sampling approach applied to determine the key players and tech suppliers.
- 33 industry experts were interviewed and a survey sent out to 40 water companies (Table 1 provides a breakdown of stakeholders interviewed).
- A workshop was organized that gathered over 40 participants to validate the preliminary research results.

Table 1: Total number of stakeholders interviewed

Stakeholder group	Total number interviewed
Technology provider (start-up)	7
Technology provider (commercialised)	3
Commodity & producer organisation (end-users)	8
Finance provider	3
sector expert/research body	5
regulatory role player	2
Incubation/skills organisation	5
Total	**33**

1.3.2. Secondary research

An extensive literature review and preliminary analysis of WSA innovations were conducted and outlined in the inception report. The literature review highlighted the following:

- Identification of key commodity sub-sectors and farming types for determining WSA market potential through a market segmentation approach.
- Identification of relevant technologies and practices with respective readiness level
- Identification of key role-players

The engagement with various stakeholders was used to validate the findings and fill the data gaps from the literature review. More importantly, the literature review provided an in-depth understanding of the WSA innovations available in the market, the underlying drivers and barriers and the current and projected uptake of innovations which are discussed in the next sections of this report.

1.3.3. Market analysis

A market analysis approach can follow a top down or bottom up. A top-down approach typically explores the market from a heuristic angle. In this approach, the total size of the market is determined and narrowed down based on the information available. This involves using publicly available information and providing assumptions about the market to determine an estimate of the market size of each segment

A bottom-up approach is the reverse. In this approach the unknown units are broken down into a set of assumptions and assessed to determine the overall market size estimate. In a business or marketing context, this would mean determining your product, the price and consumer base and expanding it at different levels (i.e. households, city, nations). It is recommended to use a hybrid approach, which is a combination of the top-down & bottom-up as they provide a full picture of the market. By applying both methods, the results of the two approaches can be validated (Alocilja & Radke, 2003; Musee & Lorenzen, 2013).

In the context of this study, both top-down and bottom-up approach were used. A bottom-up approach guided the determination of overall market estimate due to data availability of the different market segments (as shown in Figure 2). A top-down approach guided the market segmentation and included a segmentation by commodity sub-sector (i.e. field crops or horticultural), farm type (smallholder and commercial) and technology type. The market size estimates for WSA innovations were estimated based on data available for key commodity subsectors and farm types, where possible. The market segmentation approach is illustrated in Figure 2 below.

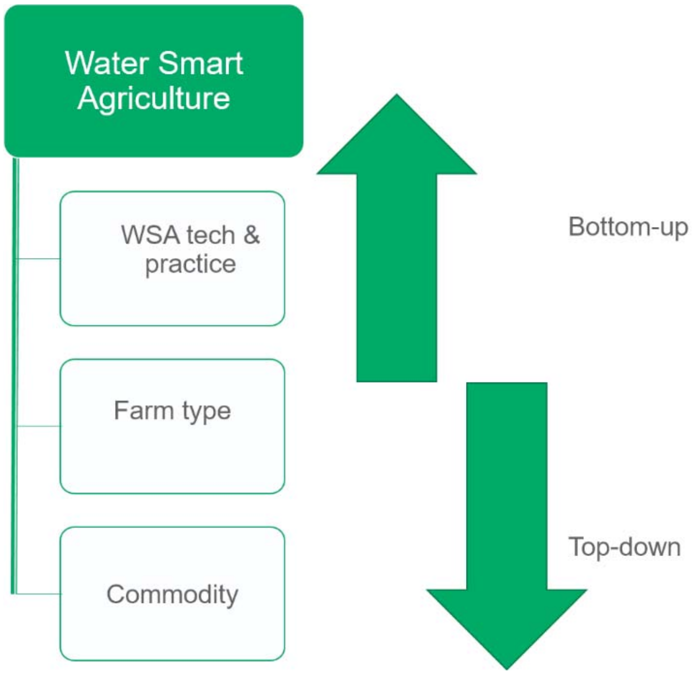

Figure 2: Market segmentation approach

The general calculation used in the literature to determine the market size estimates is outlined below (Mundy & Bullen, 2007).

$$ME = N \times MS \times P \times Q$$

Where:
ME = market size estimate
N = total number of potential consumers
MS = market share
P = average selling price
Q = average annual production

A similar calculation was applied to determine the market size estimates, however, the variables slightly vary based on the type of technology or innovation and this is noted in the relevant sections. The market size estimate[4] calculation utilised in this study is noted below:

market size estimate = potential area covered or farming units x average selling price or service

The information available also guided the assumptions made to determine the market size estimate. In an ideal case, all this information will readily be available to quantify the market size, however given the uncertainty in the information available some assumptions were made to provide an estimate of the market. Figure 3 provides an indication of some of the information that was required to determine an estimate of the market for WSA innovations in South Africa.

[4] The market size estimate highlights the segment of the available market that a technology or innovation could serve.

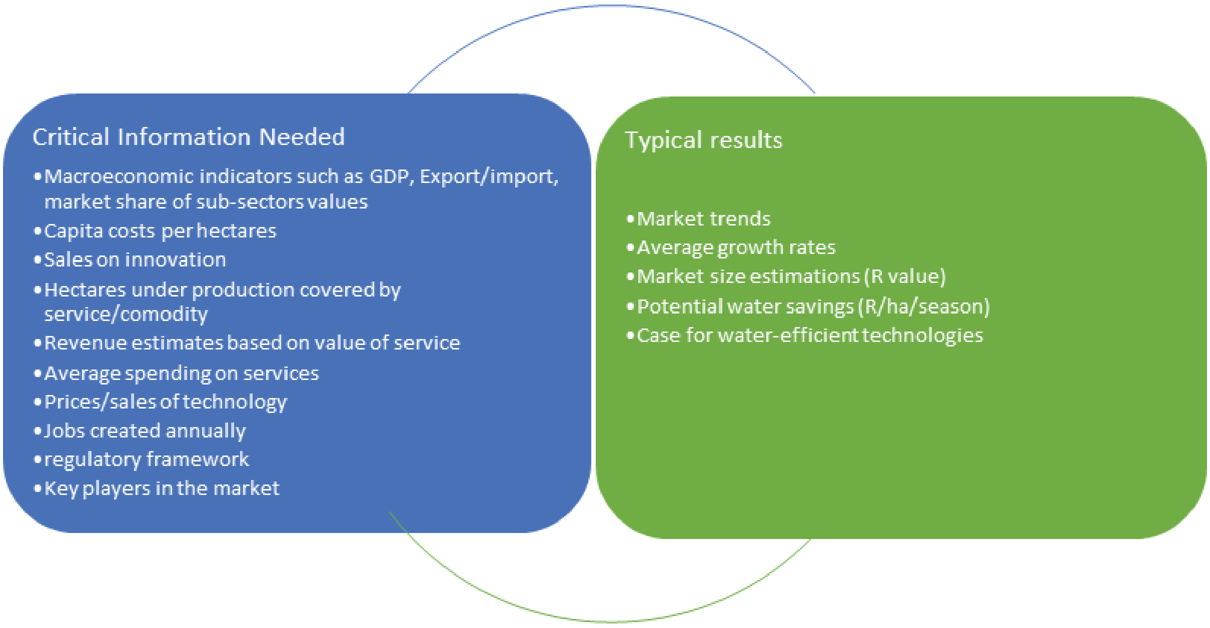

Figure 3: Conceptual framework for assessing the market potential (Wesselink et al., 2018)

1.4. Limitations of study

The ideal scenario for a market analysis would be a fully representative sample of the market dynamics, but given the data limitations, assumptions were made based on the information available, thus providing a conservative estimate of the market size. In addition, the ongoing COVID-19 pandemic had implications on the data gathering approach in the following ways:

- The survey response rate was lower than expected. The survey was sent out 40 water companies and only 8 companies responded. This could be due to businesses managing the impacts of the pandemic and thus had limited time to prioritise the survey. Therefore, where estimates were provided on sales data, this was used to estimate the market size. However, where there was no data provided, the project team referred to previous studies to estimate the market size.
- Attempts were made to conduct virtual interviews and find a representation of interview groups, but the project team struggled to secure interviews from some stakeholders, especially regulatory role players.

2. South African agriculture sector overview

The agriculture sector plays a crucial role in the development and economic growth of South Africa. This section aims to highlight the significance of the agriculture sector in terms of the production regions and farming sectors, the natural resource use and economic contribution. It further sets the scene for the market analysis by highlighting key factors that contribute to water use and innovations in the sector.

2.1. Agro-climatic regions

South Africa has a wide range of agro-climatic regions as shown in Figure 4 (FAO, 2010). The climatic regions include mediterranean, subtropical and semi-desert, enabling the production of a wide range of agricultural commodities.

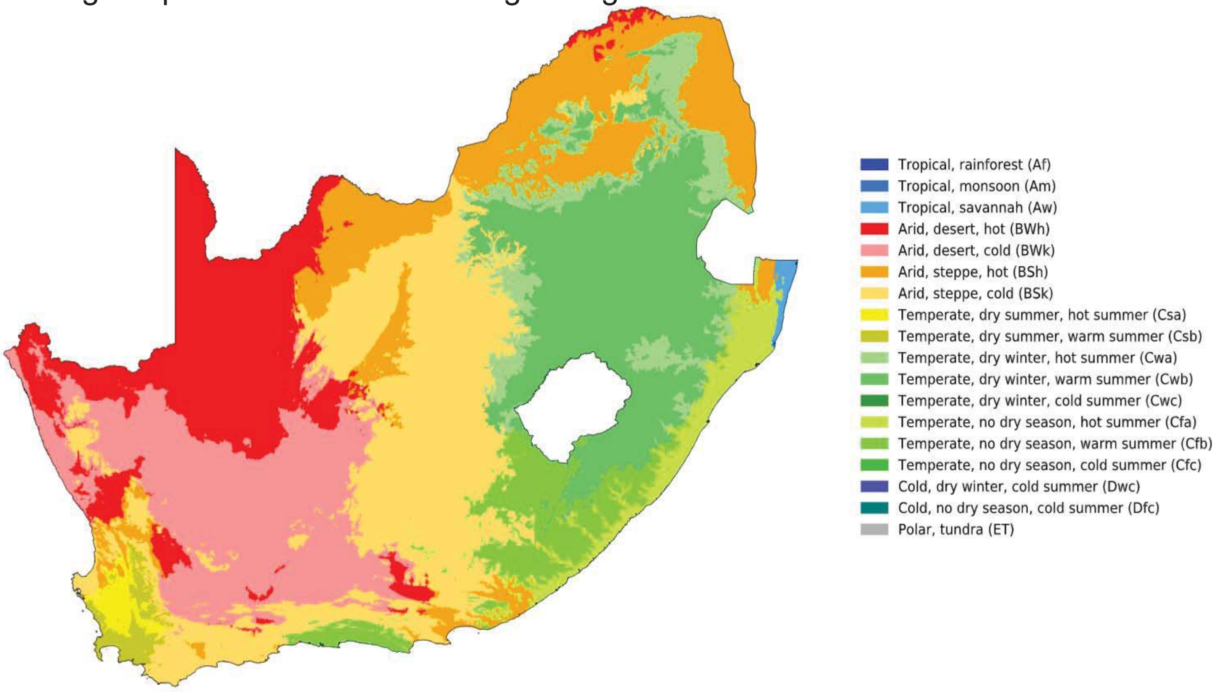

Figure 4: South African agro climatic regions (based on Köppen Geiger climate classification)

2.2. Natural resource use

Over 80% of South Africa's land surface is classified as semi-arid to arid, with an average annual rainfall of 470 mm, approximately half of the global average (FAO, 2010; WWF, 2018a). About 13% of the land in South Africa is considered arable (with an estimated 11% currently utilised for production, of which 22% has high potential and less than 10% of the total arable land is under irrigation. The country's land cover (in total 122 million ha's) and select land use classifications are illustrated in Figure 5 below (DALRRD, 2013; FAO, 2010).

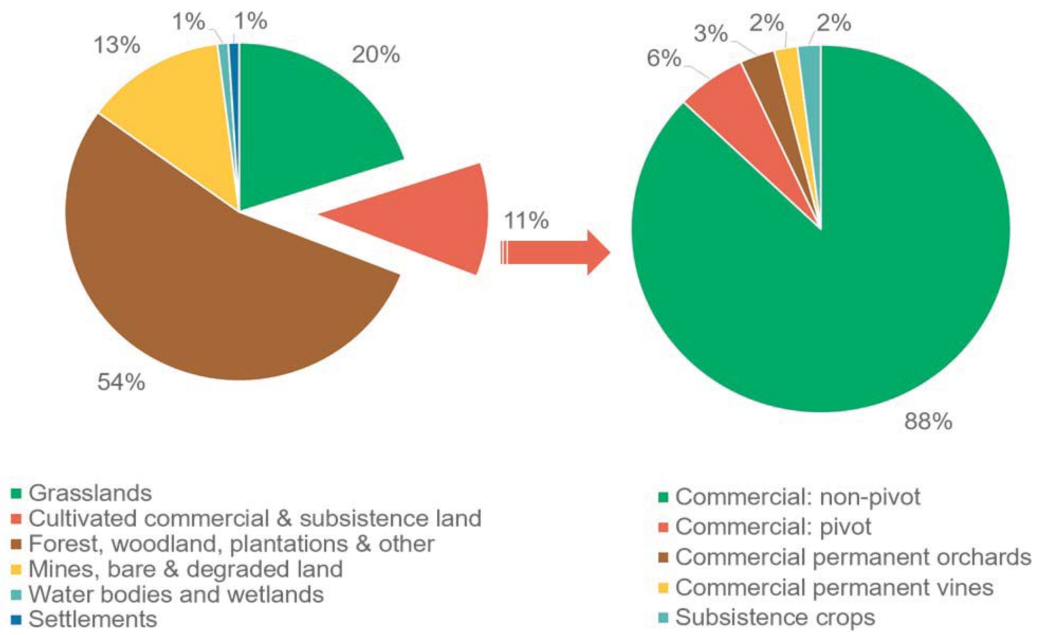

Figure 5: a) South Africa's total land use cover and b) proportional use of cultivated commercial and subsistence land cover

The majority of arable land (69%) is suitable for grazing (Schulze, 2016a). Water availability is the most limiting factor in agriculture, with rainfall generally low and erratic for rain fed agriculture, while the relatively small irrigated sector utilises ~60% of the country's stored water.

2.3. Farming sector

Agriculture in South Africa is comprised of a developed commercial sector, smallholder farming sector (typically producing for household consumption and local markets) and a subsistence sector. Smallholder farmers (often used interchangeably with small-scale farmers) are defined by the Department of Agriculture, Forestry and Fisheries (DALRRD) now called the Department of Agriculture Land Reform and Rural Development (DALRRD) as farmers owning small-based plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour. They further note that some of the main characteristics of smallholder production systems are simple, outdated technologies, low returns, high seasonal labour fluctuations and women playing a vital role in production (DALRRD, 2012a).

Consequently, emerging farmers are defined as those who emanate from the group of smallholder farmers, who were previously excluded from the mainstream of the economy. The term 'emerging farmer' does not have one standard or widely used definition in South Africa today. It is used interchangeably with the term 'black farmer', implying these farmers are a homogeneous group, although not all black farmers are emerging and vice versa. The definition of emerging farmers encompasses a wide range of farmers, e.g. those who export their products overseas and small farms that serve their immediate community. Variation thus exists depending on sub-sector and main products, however it is clear emerging commercial farmers sit at the nexus of South Africa's dualistic agriculture system (Ortmann & Machethe, 2003), characterised by commercial farming on the one end and subsistence on the other. Emerging farmers constitute a major part of what is referred to as the second economy in agriculture. They include beneficiaries of land reform programmes and new entrants who took advantage of opportunities to enter into agriculture (Senyolo & Mmatsatsi, 2007). These farmers face similar challenges to smallholder farmers.

It is critical to understand the farming profile of South Africa, as farmers are key role players in the adoption and diffusion of water smart agriculture innovations. Given that smallholder farmers and emerging commercial farmers experience similar challenges, for the purpose of this study the focus of the market analysis and opportunities was on the smallholder and established commercial farmers as categorised by Landbank (shown in Figure 6), which puts farmers on a continuum from subsistence farming to established commercial farmer.

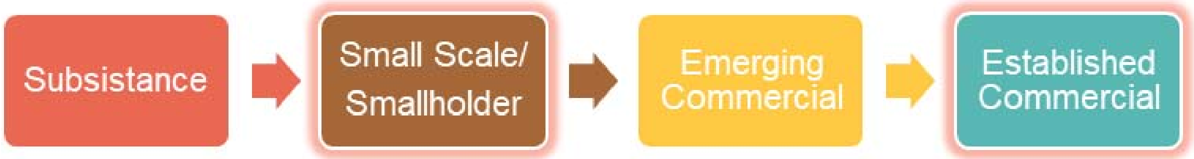

Figure 6: Classification of South Africa's farming sector

Smallholder and emerging farmers are important players to the agriculture sector's economic contribution. There are several policies in the South African agriculture sector that are dedicated to increased support for smallholder farmers and drive transformation of the commercial farming sector. Smallholder farmers provide livelihoods for ~20 million people and create demand for non-farm sector goods. Linkages with non-farming sectors become stronger when farming generates more income, i.e. commercialising smallholder production. The expansion of rural incomes through agricultural production creates a market for inputs and consumer goods and services. As a result, productivity of resources can be transferred from the agricultural sector to the rest of the economy without constraining required growth in the agricultural sector (Makhura, 2001).

2.3.1. Income contribution of different farm types

The definitions[5] of farming sectors have largely been based on the farm sizes, where, a small-scale or large-scale farm is based on hectares of land. However, farm size is not determinant of farm productivity due to the variations in land quality. Thus, recent studies and the census for commercial agriculture categorises farming types by their annual turnover. Table 2 illustrates the size of farms in commercial agriculture and number of farm units, as well as income contribution by enterprise type in 2017 (StatsSA, 2020). The majority of food produced in South Africa comes from large-scale commercial farms accounting for 64% of income contribution in agriculture sector. Although micro and small commercial farms have the highest farming units, they only contribute 28% of the income from agriculture and related services.

[5] It is worth noting that defining and classifying farming types (i.e. emerging farmer versus smallholder or subsistence farming) is still a topic of debate in the country.

There is a lack of data on the number of farming units for commercial farmers not registered for VAT and smallholder farmers – rough estimates based on various surveys and census reports suggest 30 000 and 280 000 farming units respectively.

Table 2: Farm sizes, income contribution and number of farming units for different commercial farm types (2017)

Commercial farm size	Turnover p.a.	% Contribution to income from agriculture and related services	Number of farming units
Large	Turnover> R22 500 000	64%	2608
Medium	R13 500 < turnover< R22 500 000	8%	1846
Small	R 2 250 000< turnover< R 13 500 000	20%	10713
Micro	turnover < R 2 250 000	8%	24 956
Total			**40 122**

Source: (StatsSA, 2020)

2.4. Economic overview

Water is an important input for agricultural production and thus contributes to economic development. The demand for water uses is increasing in response to economic growth, growing population and urbanisation. Thus, understanding the economic trends in the agriculture sector provides some indication on the demand and significance of water resources. This section provides an overview of the economic contribution of South Africa's agriculture sector, the key commodity sub-sectors as well as the associated trade performance.

2.4.1. Gross Domestic Product and Employment

Although primary agriculture contributes a relatively small share of the total South African economy in terms of GDP (~3%) including downstream agricultural value added activities known as the agro-processing sector, this contribution increases to 7% (see Figure 7). Employment in the agriculture sector has seen more substantial growth over the past decade as shown in Figure 8, growing at a rate of 16,9%.

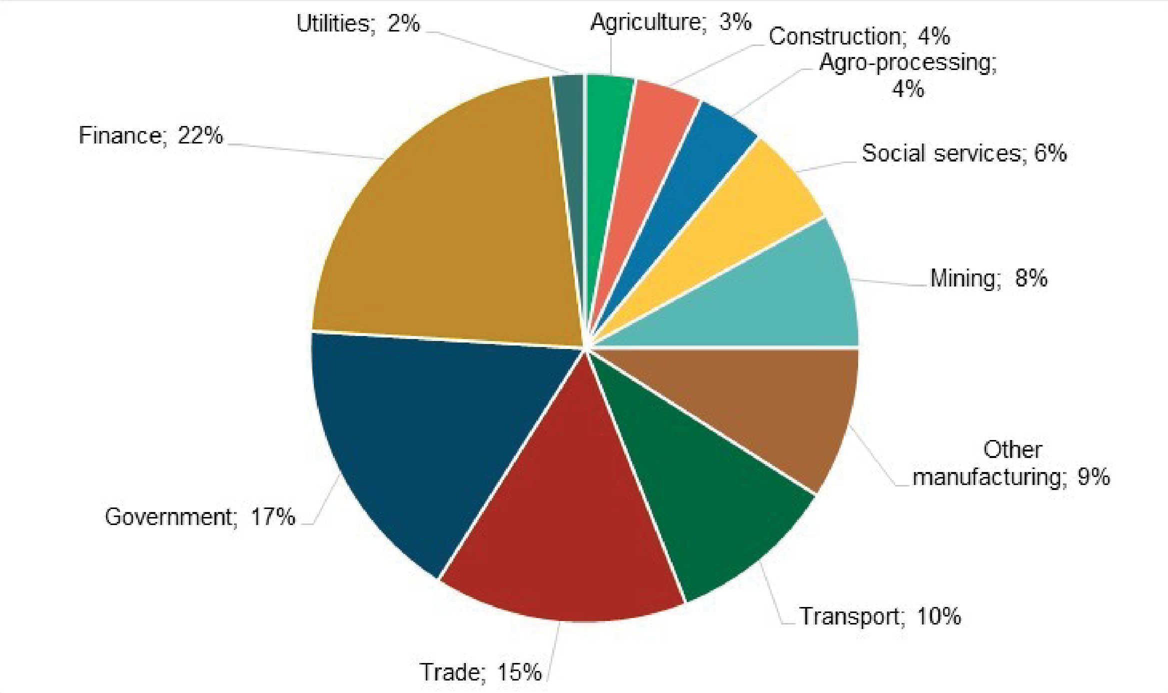

Figure 7: South African sectoral GDP (Quantec, 2019)

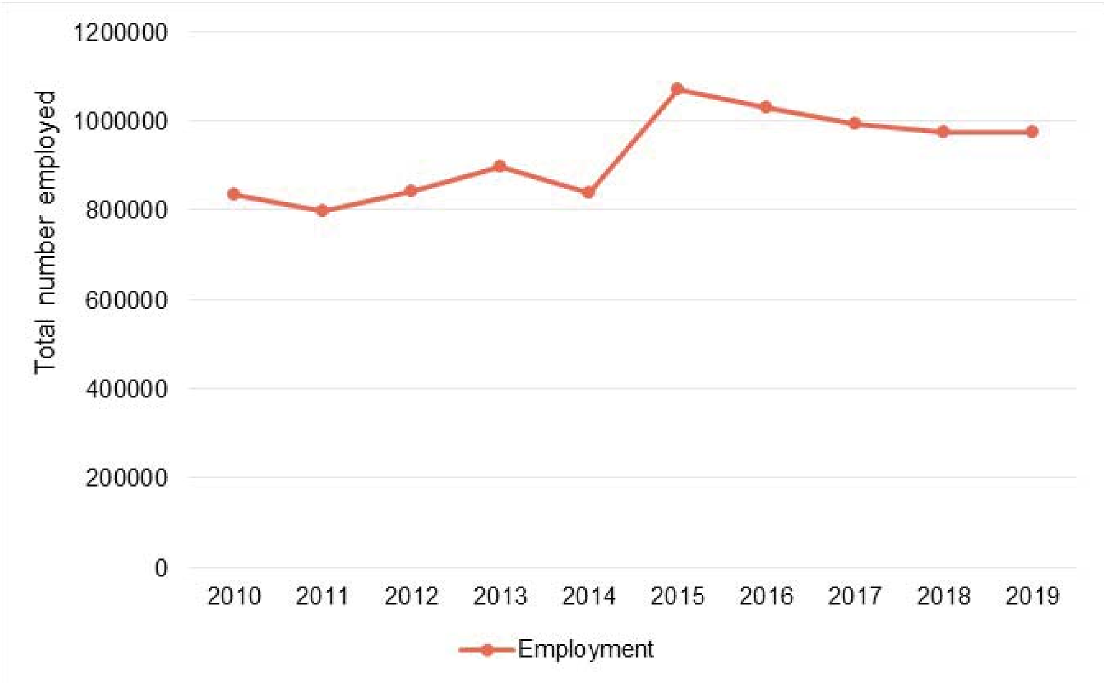

Figure 8: Total number of people employment in the agriculture sector (Quantec, 2020)

2.4.2. Gross value of agricultural production

The total gross value of agricultural production (total production during the production season valued at the average basic prices received by producers) for 2019/20 is estimated at R319 732 million. The gross value of animal products, horticultural products and field crops contributed 44.20%, 31.50% and 24.30%, respectively to the total gross value of agricultural production in 2019/20 as illustrated in Figure 9 below.

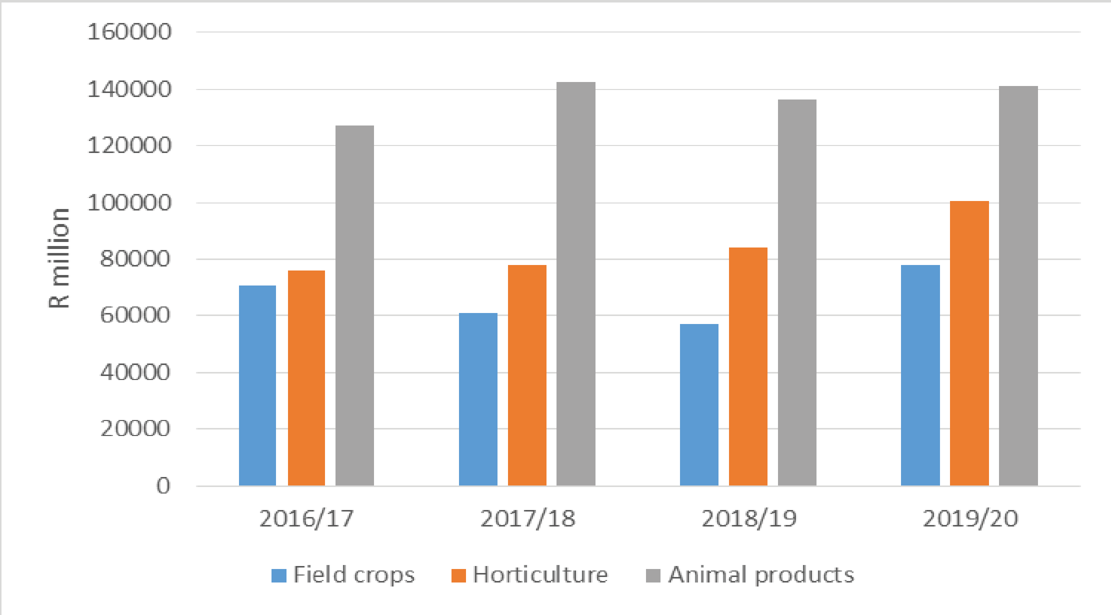

Figure 9: Gross value of agricultural production by commodity sub-sector (2016-2020) (DALRRD, 2020)

2.4.3. Income and expenditure

The average 'gross income', 'expenditure on intermediate goods and services' and 'net farm income' from agriculture between 2010-2018 was R213, R115 and R21 billion respectively. The main contributions of income earned in the agriculture and related services industry were from 'animals and animal products' (42%), followed by 'horticultural crops and products' (25%) and 'field crops' (19%) (DALRRD, 2019a). Figure 10 below shows income by enterprise size and related service industry.

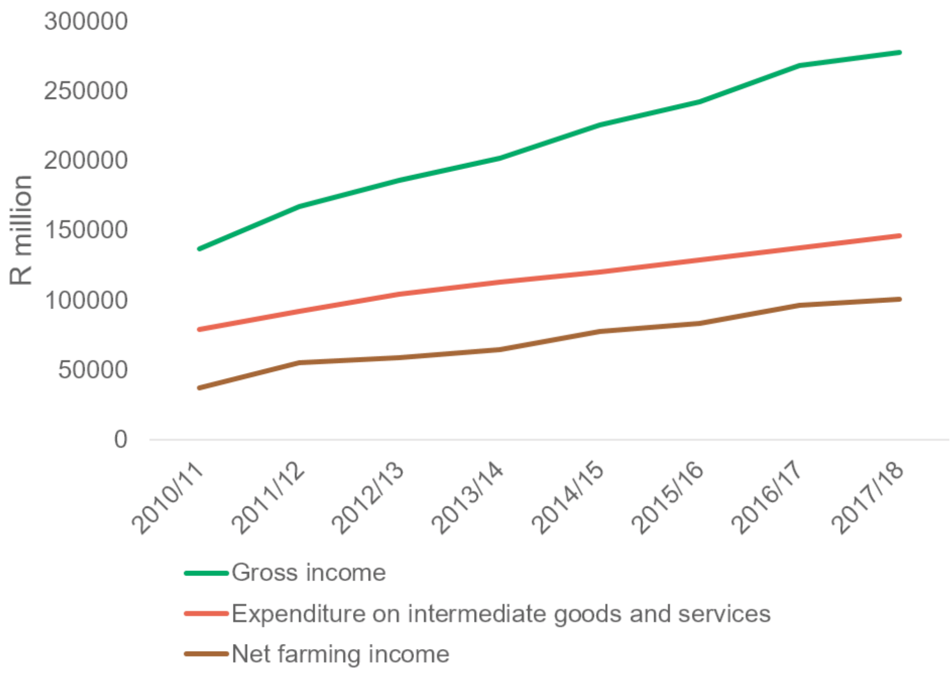

Figure 10: Income and expenditure trends in the agriculture and related service industry (2010-2018) (DALRRD, 2019a)

2.4.4. Agricultural trade

South Africa is known as a net exporter of agricultural goods, exporting more than 30% of its goods. Agricultural trade plays a key role in economic growth as it provides jobs, generates foreign exchange and stimulates international investment and development of new infrastructure. Figure 11 elaborates the trade performance of agricultural and related products since 2010. South African agricultural exports have performed well, growing from R25 billion in 2010 to more than R69 billion in 2019 (using current prices) and the agricultural trade balance has also improved from R16 billion in 2010 to R49 billion in 2019, despite imports of agricultural products also expanding during the same period.

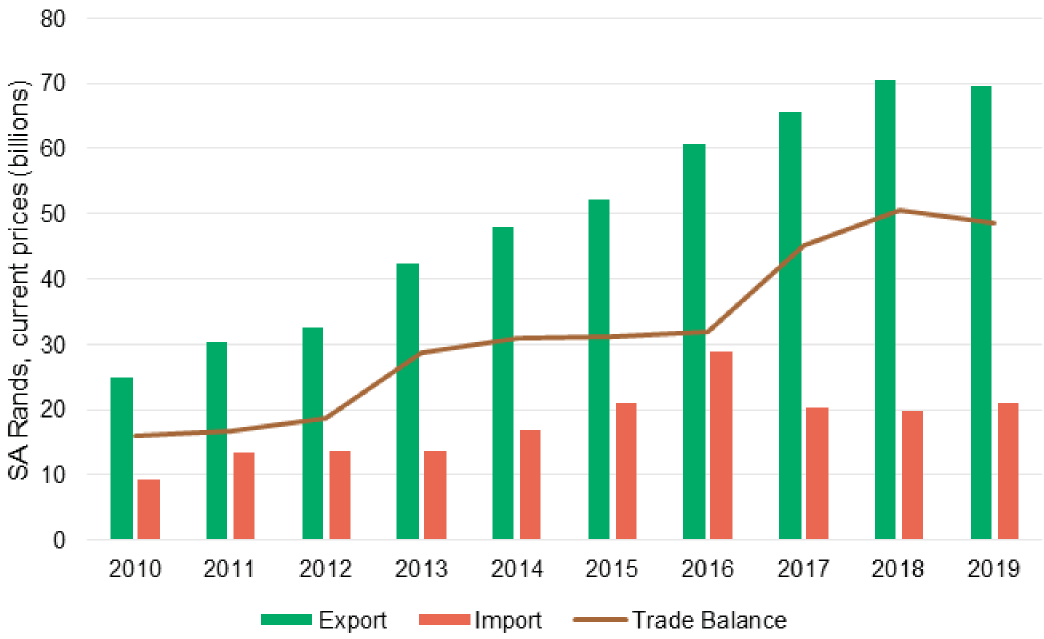

Figure 11: South African exports and imports (2010-2019) (Quantec, 2020)

The key global markets for agricultural products are Europe, Asia and Africa. As indicated in Figure 12, Europe accounted for 40% of the total agricultural exports in 2019, followed by Asia accounting for 34% of the total agricultural exports and Africa at 19%. There are trade agreements and regulations in these regions that present opportunities as well as risks for water smart agriculture innovations. These are explored in relevant sections in section 5.

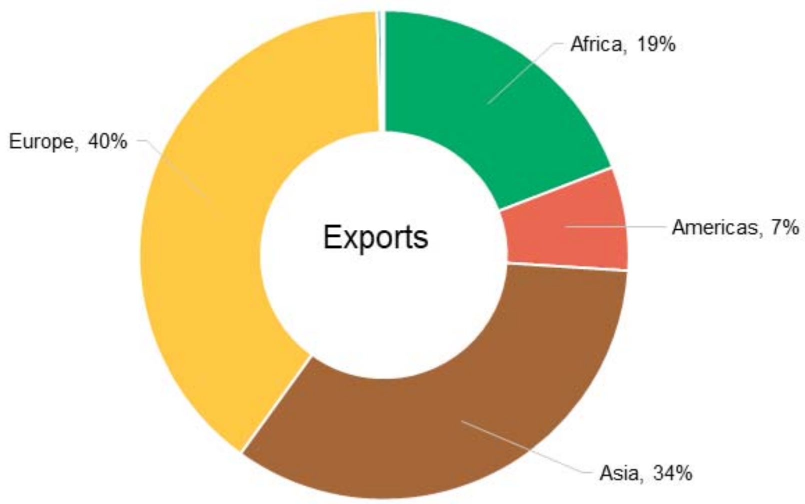

Figure 12: South Africa's export destinations for agricultural products (Quantec, 2020)

3. Agricultural commodity trends

This section highlights key agricultural sub-sectors and trends that impacts on the WSA market potential[6].

3.1. Major agricultural products in South Africa

South Africa has a range of climatic regions that allows for diverse agricultural produce. The agricultural activities range from intensive crop production and mixed farming in high rainfall regions to cattle and sheep farming in more arid regions. The different agricultural regions and activities in South Africa are illustrated in Figure 13.

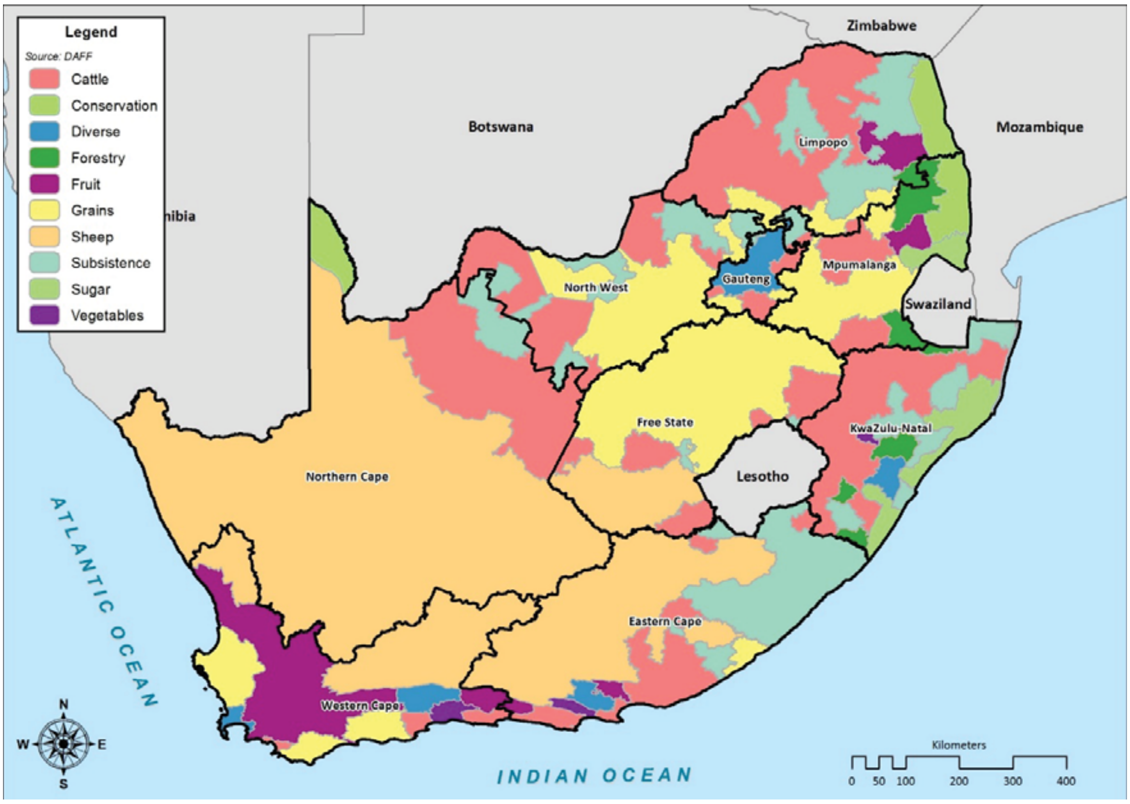

Figure 13: South Africa agricultural regions (FAOSTAT, 2010)

The major crops in South Africa by volume include sugarcane (19.48 million tonnes), maize (11.27 million tonnes), potatoes (2.50 million tonnes) and grapes (1.99 million tonnes). The top ten crop by production volume in South Africa are shown in Figure 14.

[6] The market potential refers to the market that can be captured in future. This has been highlighted based on commodity and regulatory trends that are likely to impact on the uptake of the innovations.

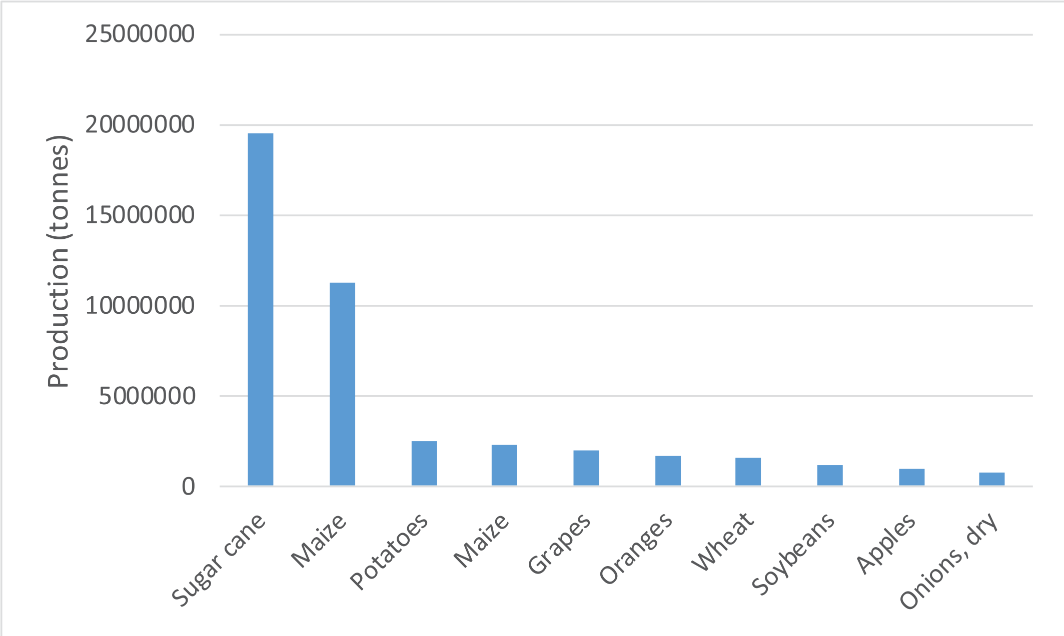

Figure 14: Major agricultural crops by production volume in South Africa, 2019 (FAOSTAT, 2020)

3.2. Production trends

This section outlines an overview and outlook of the different agricultural products in the context of the potential for WSA innovations.

3.2.1. Horticultural production

A wide variety of fruits and vegetables are grown in South Africa, due to the country's climatic diversity. Vegetables have been the largest contributor of gross farm income from horticultural products for the past five years as illustrated in Figure 15. The contribution from deciduous fruit declined in 2018 by 19% but was considerably higher in the previous years, while the income from citrus fruit increased in 2018. Subtropical fruits make up the lowest contribution to the gross farm income of horticultural products and have been fairly consistent over the past four years.

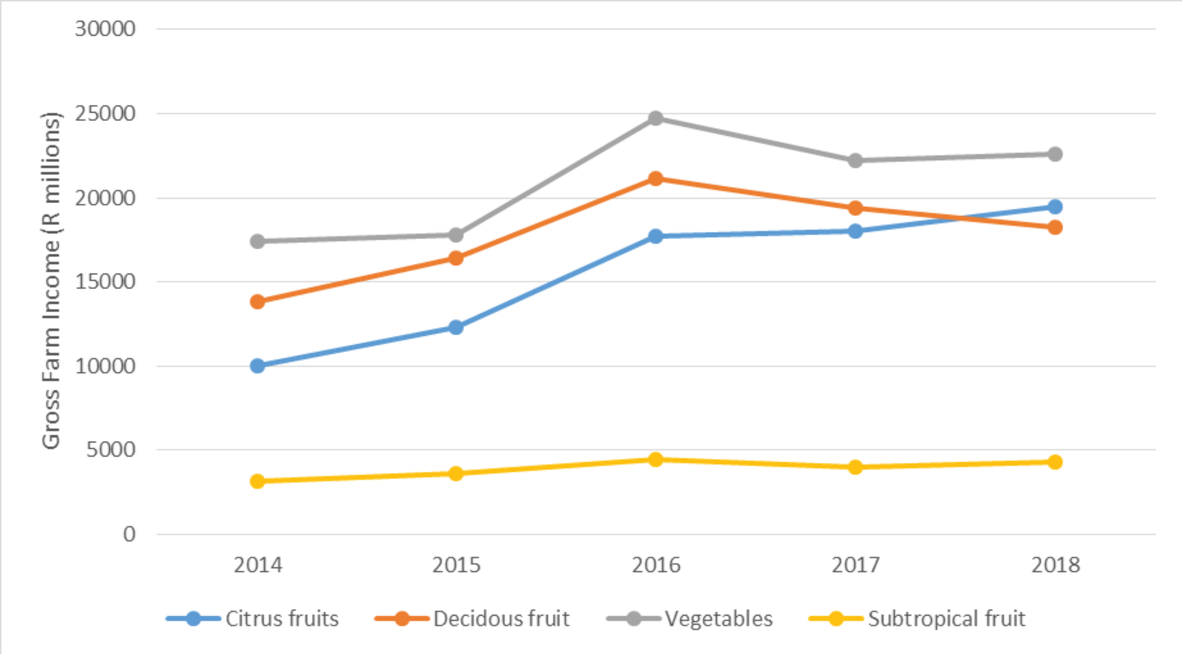

Figure 15: Gross farm income of horticultural products (DALRRD, 2019b)

3.2.1.1. Vegetables

Vegetables are produced across the country, with the Free State, Limpopo, Western Cape and KwaZulu-Natal being among the largest producers. The major vegetables in production quantity are potatoes, tomatoes, onion, and cabbages as shown in Table 3 (DALRRD, 2019b).

Table 3: Production volumes of vegetables

Vegetables	**Production (tonnes)**
Potatoes	2 468 000
Onions	724 000
Tomatoes	558 000
Green mealies and corn	394 000
Pumpkins	265 000
Carrots	217 000
Cabbage	161 000
Other	669 000
Total	**5 456 000**

Source: (DALRRD, 2019b)

Approximately 46% of the vegetables produced are traded on major fresh produce markets and 43% is for direct sales and own production. Only 5% of the vegetables produced are exported (DALRRD, 2019). Thus, the vegetable market is primarily driven by local demand. Population increase and improved standard of living is expected to drive the demand for high value and quality fresh produce.

The COVID-19 pandemic has had an impact on food budgets and disrupted fresh produce markets. As a result, it is estimated that in the short term the demand for fresh produce will decline. In addition, decreased water availability and allocation is further anticipated to drive producers to reduce the area of potatoes planted. According to the Bureau for Food and Agricultural Policy (BFAP), the demand for potatoes was estimated to decline by 85 000 tonnes in the short term. However, the demand for potatoes is expected to increase in the longer term and is projected to increase by 0.8% per annum to 2.61 million tonnes in 2029 (BFAP, 2020).

3.2.1.2. Deciduous fruit

Deciduous fruits are widely grown in the Western Cape and Eastern Cape regions, with smaller quantities grown in the Free State and Mpumalanga. The area under deciduous fruit production during the 2018 season is estimated at 54 052 ha (Hortgro census). The fruits grow best in areas where there are dry summers and cold and wet winters. The most widely produced of the deciduous fruits are apples, pears and table grapes as shown in Table 4. In the 2018/2019 production season, about 884 000 tonnes of apples were produced showing an increase of 5.1% from the previous year, followed by pears at 406 433 tonnes with an increase of 3.5% and table grapes at 140 158 tonnes with a decrease of 25.2% from the previous year (DALRRD, 2019b).

Table 4: Production volume of deciduous fruits in 2018/19

Fruit type	**Production (tonnes)**
Apples	884 141
Pears	406 433
Table grapes	314 835
Peaches & nectarines	140 158
Plums	58 815
Apricots	26 303
Total	**1 830 685**

Source: (DALRRD, 2019b)

The exports of deciduous fruit is quite significant in South Africa, about 53% of deciduous fruit produced was exported and 77% of the GVA from deciduous fruit in 2019 came from export earnings. The export of apples is expected to increase by 16% by 2027, while pear exports are projected to increase by 7.8% over the same period. Tree bearing fruits were significantly affected by the drought in the Western Cape, and complete recovery is expected to take several years. Due to irrigation constraints, apple production is expected to only increase by 5.3% over the period 2017 to 2027, while pear production is projected to increase by 1.9% (BFAP, 2018).

3.2.1.3. Citrus

Citrus products were the second largest contributor to the gross income for horticultural products in 2018/19 as illustrated in Figure 15. Citrus farming occurs in areas with hot summers and mild winters. In South Africa, citrus is widely grown in Limpopo, Eastern Cape, Mpumalanga, Western Cape and KwaZulu-Natal provinces. The area under production for citrus is estimated at 83 490 ha in 2018/19. The major citrus commodities include oranges, grapefruit, lemons, naartjies and soft citrus. Oranges account for about 65% of the farming gross income of citrus.

South Africa is one of the major exporters of citrus fruit. According to SEDA (2012), the industry is made up of approximately 1300 export farmers and 2200 small farmers that meet the minimum requirement of the domestic demand. The growth of the industry in both exports and production is expected to continue growing over the next decade, however at a significantly slower rate. Water constraints and weaker prices are anticipated to limit the growth rates. The production of oranges is expected to grow from 1.66 million tonnes in 2020 to 2.11 million tonnes in 2029, while soft citrus and lemons & limes is projected to grow respectively, from 409 866 tonnes and 533 257 tonnes in 2020, to 521 012 tonnes and 689 496 tonnes by 2029 (BFAP, 2020).

3.2.1.4. Subtropical fruit

Subtropical fruits are grown in warmer conditions and sensitive to temperature fluctuations. The areas in South Africa where majority of subtropical fruits are produced are in Limpopo, Mpumalanga and KwaZulu-Natal provinces. Other subtropical fruits can be found in the Western Cape and Eastern Cape provinces.

The production of subtropical fruit in 2018/19 is illustrated in Table 5. The total production of subtropical fruit increased by 9.7% from 732 363 tonnes in 2017/18 to 803 200 tonnes in 2018/19. The fruits that contributed to this growth were granadillas which increased by 33%, followed by avocados at 33.1%, mangoes at 24.7%, pineapples by 10.7% and bananas at 3.3%.

Table 5: Production volume of subtropical fruit (2018/19)

Fruit type	Production (tonnes)
Avocados	114 500
Bananas	416 500
Pineapples	115 500
Mangoes	110 700
Papayas	10 400
Granadillas	800
Litchis	7 900
Guavas	26 900
Total	**803 200**

Source: (DALRRD, 2019)

The demand for avocados has grown rapidly in the past 10 years. The high growth of the industry has resulted in expansion of hectares with some farmers diverting away from other crops such as bananas, mangoes, sugarcane and commercial timber. Avocados are the main subtropical fruit type being exported and contributed about 80% to the total value of exports of subtropical fruits in 2018/19. Other fruits types exported included litchis, mangoes, pineapples and papayas. The avocado industry is projected to continue growing and is expected to expand by 34 000 ha and 300 000 tonnes by 2029 (BFAP, 2020).

3.2.1.5. Water requirements

Horticultural products differ in their water requirements and have varied stages of growth which affect the water use. The estimated evapotranspiration (ET) or water requirements of some deciduous fruits and vegetables is illustrated in Table 6 (V.A. Niekerk, 2018). The highest estimated water use were identified in irrigated citrus fields (925 mm/yr) grown in summer rainfall regions, pome fruit (828 mm/yr) and table grapes (791 mm/yr) grown in winter rainfall regions. The lowest was identified in rain-fed wine grapes (528) and other irrigated fruits (527 mm/yr).

Table 6: Estimated water requirements for horticultural crops

Crop type	Rainfall season	Group	Mean ET (mm/yr)
Vegetables	Summer	Irrigated	789
		Rainfed	639
Grapes – Table	Winter	Irrigated	791
Grapes – Wine	Winter	Irrigated	598
		Rainfed	528
Grapes – Other	Summer	Irrigated	754
Fruit – Citrus	Winter	Irrigated	696
	Summer	Irrigated	925
Fruit – Stone	Winter	Irrigated	655
Fruit – Pome	Winter	Irrigated	828
Fruit – Other	Winter	Irrigated	572

Source: (V. A. Niekerk, 2018)

Fruits and vegetables are critical to the South Africa economy. However, the growth of the different commodities is constrained by scarce water resources. Irrigated crops require the highest amount of water, with citrus and pome fruit being the most water intensive. Given the expected increase in consumption of potatoes and expected export growth of citrus and apples, production of horticultural crops provides some potential for the adoption of WSA innovations.

3.2.2. Animal production

The livestock sector has the largest share of number of farms in the country and is the highest contributor to the gross farm income (DALRRD, 2019b). Approximately 80% of agricultural land in South Africa is suitable for extensive livestock farming. Cattle, sheep and goat farming make up 590 million ha (approximately 53%) of all agricultural land. Livestock farming is practiced across the country, but predominately occurs in the Eastern Cape, KwaZulu-Natal and North West provinces (DALRRD, 2019d). Some of the key commodities in terms of gross farm income of animal products include poultry meat, cattle, milk, eggs and sheep as shown in Figure 16.

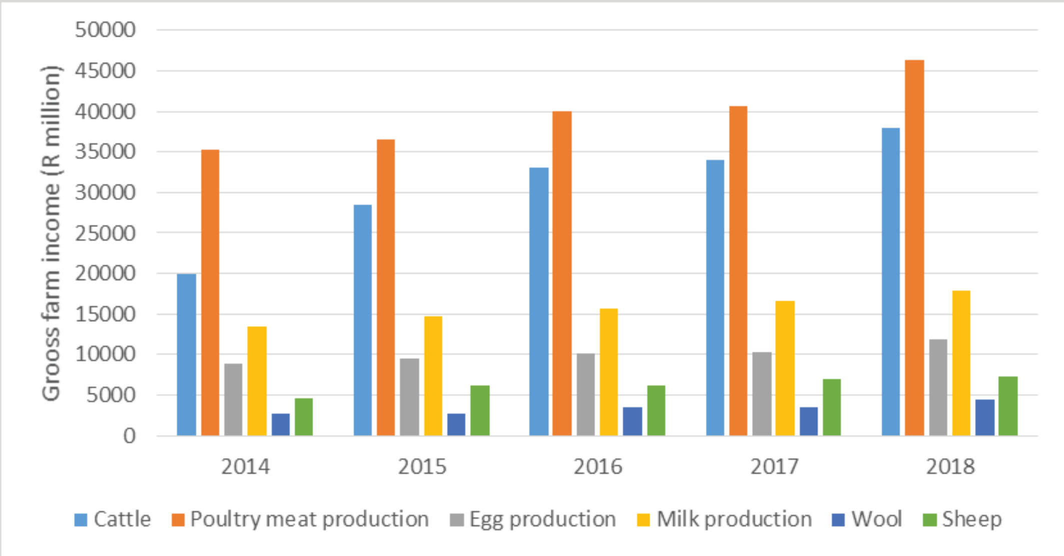

Figure 16: Gross farm income of animal products (DALRRD, 2019)

3.2.2.1. Water requirements

There is a growing need to increase water efficiency and productivity in the livestock sector given the increasing demand for animal protein that is driven by population growth and rising incomes that will lead to diversified diets. The sector is a major user of natural resources such as land and water. Water is consumed directly and indirectly across the livestock production system. Direct water consumption for livestock includes:

- on-farm irrigation water (feed/pasture production);
- drinking water at farm stage (primary production and;
- services and processing water (at farm, slaughtering stages, cleaning and cooling stages).

Indirect water use includes irrigation water of purchased feed; water used to generate electricity for the production chain, and water used in the production of fertilizers and pesticides (FAO, 2019). There are several estimates on the water footprint and requirements of the livestock production system. Table 7 illustrates some of the major pastures and the water requirements.

Table 7: Water requirement for pastures

Pastures	**Water requirements**
Dryland	
Weeping lovegrass	Adapted to summer and winter rainfall exceeding 650 mm/annum
Smuts finger grass	Grows best in areas with rainfall 450/annum
Foxtail buffalo grass	Grows in areas receiving rainfall below 300 mm/annum
Irrigated	
Lucerne	Annual water requirements of 1100-1200 mm
Kikuyu grass	Rainfall must exceed 700 mm/annum to obtain optimum production

Source: (Krüger, 2016; Truter et al., 2016)

Given the significance of this sector to the economy and the potential demand for animal protein, WSA innovations applicable to this sector are centered the on-farm production stage (i.e. feed production).

3.2.3. Field crops

Field crop production in South Africa can be divided into summer crops and winter cereals. Some of the major field crops include maize, sugarcane, wheat, soybeans. These are important in terms of the contribution to gross value of field crops and production quantities illustrated in Figure 17 (DALRRD, 2019d) and Figure 18 (FAO, 2018). The section below gives an overview of the key commodities, outlook and water requirements of the different commodities.

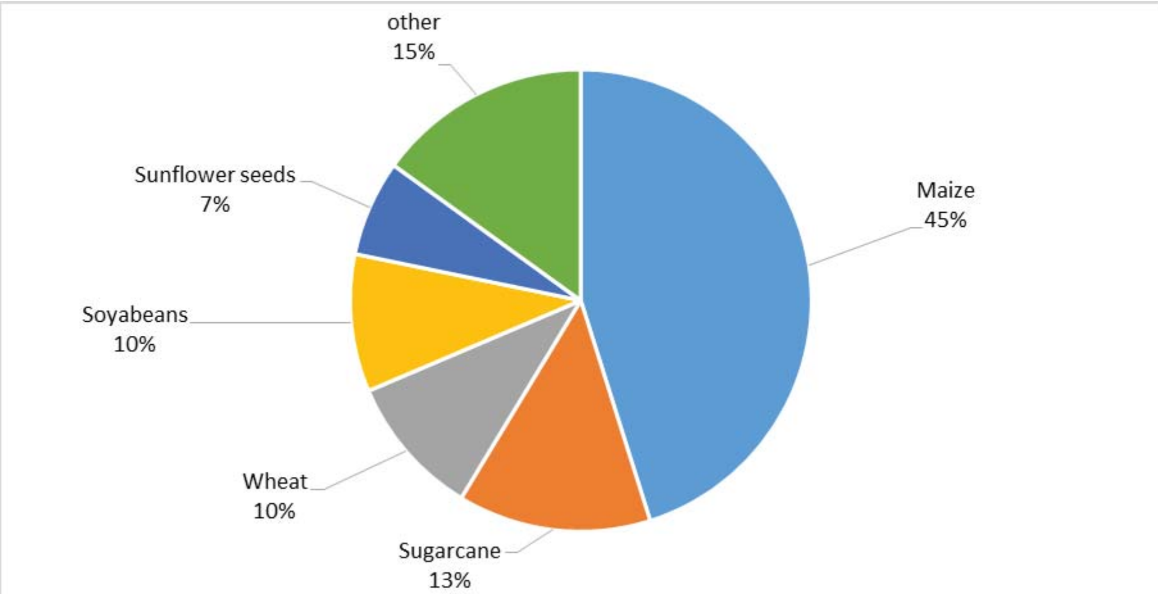

Figure 17: Gross value add of major field crops (DALRRD, 2019)

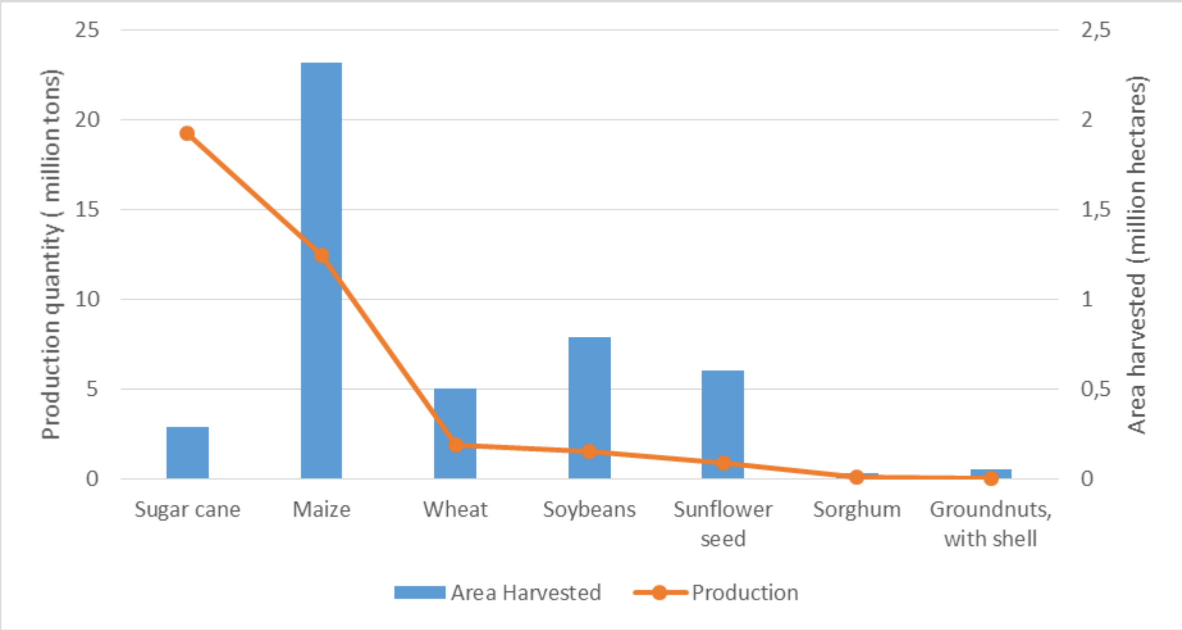

Figure 18: Area harvested and production quantity of field crops for 2018 (FAOSTAT, 2018)

3.2.3.1. Maize

Maize is an important staple food for the majority of the SA population and a major feed grain. About 80% of area harvested for field crops is maize. It is largely grown in the Free State, North West and Mpumalanga in two varieties, white and yellow accounting for 85% of total production. Approximately 56% of the maize produced is white and 44% yellow. Maize is mainly produced under dryland conditions, only 5% of white maize and 14.4% of yellow maize is cultivated under irrigation (DALRRD, 2018).

Majority of the maize produced is consumed locally, making it an important commodity for the domestic market. White maize is predominately grown for food consumption, whereas yellow maize is mostly used as animal feed. The maize industry is comprised of both commercial and non-commercial farmers. It is estimated that there are about 6500 commercial maize producers and thousands of small-scale producers contributing to meet the local demand. The area harvested by non-commercial farmers in 2018/19 was estimated at 296 000 ha and 2 300 500 ha for commercial farmers.

The demand growth for white maize varies from that of yellow maize. While it was previously projected that the growth of white maize in the short-term will decline as result of rising incomes driving dietary diversification and a shift from white maize consumption, the economic downturn in 2020 has slightly shifted this outlook. The per capita consumption of white maize is projected to increase by 0.5% per annum over the next 10 year. The growing population will further result in an increase of 14% of white maize consumption by 2029. The demand for yellow maize consumption as animal feed is similarly projected to increase by 22% in 2029 (BFAP, 2020).

3.2.3.2. Sugarcane

Sugarcane is a tropical crop that is largely grown in South Africa for sugar production. Sugarcane growers are predominately in KwaZulu-Natal and Mpumalanga and some operations in the Eastern Cape. Most of the sugarcane produced is rain-fed, but in the northern parts of KwaZulu-Natal and Mpumalanga regions, sugarcane is produced under irrigation (DALRRD; BFAP, 2018).

Sugarcane is an important crop in South Africa, contributing about 13% to GVA of field crops. It was the largest commodity in 2019 in terms of production quantity. The sugar produced in the country is globally competitive given the high-quality infrastructure available in the industry. About 60% of the sugar produced is sold in the Southern African region, with the remainder exported to other regions. The growth projections for the sugar industry are declining due to the high import tariffs and low-profit margins. Farmers are seen shifting away from sugarcane and diversifying to more long-term crops resulting in an expected loss of 36 000 hectares from 2022 to 2029 (BFAP, 2020).

This loss in productivity in the sugarcane industry has resulted in the development of the South African Sugar Masterplan. The masterplan aims to boost the competitiveness of the industry through some of the following actions:

- Restoring local market and offtake agreements
- Providing trade protection to local sugar industry
- Placing measures to ensure viability of small-scale growers.

3.2.3.3. Wheat

Wheat is the third most important grain in terms of production quantity and contribution to GVA of field crops. It is mostly grown in the Western Cape and the Free State. It is grown under dryland and irrigation conditions in the summer rainfall regions and under dryland conditions only in the winter rainfall regions. Approximately 503 000 ha of wheat was cultivated in 2018/19 production season. In SA, wheat is mainly grown for food consumption and the remainder is used as seed and animal feed. Other non-food uses include alcohol production and industrial uses such as starch on coatings. There are approximately between 3800 to 4000 wheat producers. South Africa is the largest wheat producer after Ethiopia in sub-Saharan Africa.

The production of wheat declined by 9.2% from the previous year in the 2018/19 production season as a result of the drought conditions in the Western Cape and reduced global prices that led to reduction in producer revenue. The area under irrigation of wheat products is expected to be fairly constant, facing competition from long term crops[7] for scarce resources such as water. The demand for wheat is anticipated to grow given the population growth increasing consumption by about 1.2% per annum in the next decade.

South Africa is a net importer of wheat and relies on imports from Russia, USA, and Czech Republic to meet local demand. About 1369 million tonnes of wheat was

[7] Long-term crops are crops that require more than 5 years to grow before harvesting is possible and they are able to generate cash flows

required in 2019 to meet domestic consumption. Wheat production is forecasted to reach 2 million tonnes, suggesting that import requirements of 1.85 million tonnes to meet the domestic demand in 2027 (BFAP, 2018).

3.2.3.4. Soybeans

The production of soybeans in South Africa ranges from 700 000 tonnes to 1500 000 tonnes per annum at an average yield of 2t/ha under dryland production. Mpumalanga is the province producing soya beans in large quantities of about 42% of the total harvest. The Free State produces about 22% of the total harvest, while KwaZulu-Natal produced 15%, Limpopo 8%, the North West 5% and Gauteng 2%. Soya beans grow best at moderate temperatures and receiving rainfall of 500 to 900 mm, depending on the growth conditions (DALRRD, 2010).

Soybeans contributed about 8.5% to the gross value of field crops in 2019. It is among the fastest growing field crops over the past decade in area and production, increasing at about 15% and 20% respectively per annum. The area under production is projected to expand by an annual average of 3.9% by 2027. The growth of soybeans is driven by an expected rise in feed consumption and an increase in domestic demand for soybeans. There has also been a rise in the export of soybeans (GrainSA, 2017). In addition, the potential growth of soybeans is also attributed to the uptake of farming practices and investments in improved seed varieties and mechanization. These investments are anticipated to start paying off in the coming years (BFAP, 2018).

3.2.3.5. Water requirements

The crop water needs for different field crops vary. Table 8 (WRC, 2018) provides an estimate of the water requirements of different field crops. Irrigated sugarcane has the highest water requirement of field crops. Most of the rain-fed crops have a moderate water requirement that ranges between 500 and 655 mm/yr.

Table 8: Estimated water use (ET) for different field crops

Crop type	Rainfall season	Group	Mean ET (mm/yr)
Maize	summer	Irrigated	764
		Rainfed	610
Wheat	Summer	Irrigated	655
		Rainfed	581
Other small grains	Summer	Irrigated	663
		Rainfed	586
Oilseeds		Irrigated	628
		Rainfed	504
Sugarcane		Irrigated	914
		Rainfed	732

Source: (V. A. Niekerk, 2018)

3.2.4. Niche industries

In addition to the crops highlighted in the previous sections, the National Development Plan (NDP) highlights plans to grow niche industries such as macadamia, olives, berries, and figs. These industries show high growth potential as they do not compete with existing industries. The berries and nut industry are among those showing high growth. Figure 19 shows the growth of crop industries and farm-level employment per hectare in 2018. As indicated, the blueberry industry has grown significantly compared to other crops, growing at a 5-year annual growth in value of ~55%. The nuts industry is also among the crops showing high growth of ~21% per annum.

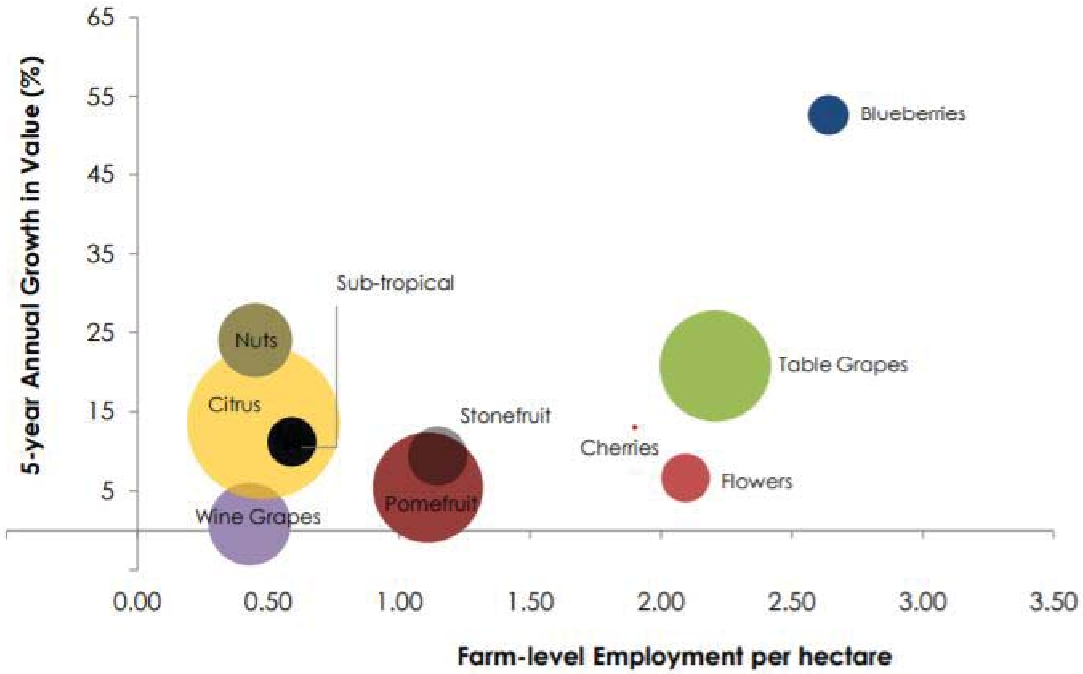

Figure 19: Comparison of growth and jobs in crop industries (WCDoA, 2019b)

3.3. Summary of key commodity sub-sectors

This section explored some of the key sub-sectors and commodities in the South African agriculture sector. The production trends and outlook of each sub-sector were outlined with specific focus on gross farm income, contribution to GVA, production volumes, potential growth and estimated water requirements. It was reflected that population growth and rising incomes are some of the key drivers of growth for the different commodities. However, the COVID-19 pandemic has affected food budgets and incomes in the short-term, resulting in demand for more affordable food crops such as white maize. In addition, water scarcity was noted as a key barrier to productivity of the agricultural products. These market dynamics and trends present an opportunity for WSA innovations.

4. Water-Smart Agriculture innovations

This section provides an overview of the major agriculture innovations trends at both international and national level, defines water smart agriculture innovations in the context of this study, and the major drivers to the uptake of water smart agriculture innovations.

4.1. Water smart agriculture innovations

Innovations have varied definitions and are often context specific. According to the Organisation for Economic Co-operation and Development (2005), an innovation is defined as the implementation of something new or improvement in products, processes, marketing or organisational methods at a significant scale. There are various ways in which innovations can be classified. Innovations can be classified based on the kind of shift or “chaos” they create in the market or how they are used to improve and add value (i.e. product, process, marketing or organisational innovation) or based on who implements the innovation (i.e. entrepreneurial or institutional). The varied innovation categories are:

- *Technological innovation*: new ideas to goods produced and services delivered
- *Process innovation*: changes to the way goods or services are delivered often considered as knowledge systems and products
- *Social innovation*: development or improvement in strategies, ideas to respond to social needs
- *Marketing innovations*: new methods and changes in product design, packaging, promotion or pricing
- *Institutional innovations*: changes in policies, standards or regulations that create an improved enabling environment.

Agricultural innovations are defined as technologies, practices or product handling techniques that result in increased yields or income to the farmer. The different innovations can encompass a combination of hardware and software technologies (such as drone technology and analytical services) or tools that guide decision making processes on and off-farm (Hall et al., 2005). Agricultural innovations that result in increased food, using limited amount of farmland, while reducing greenhouse gas emissions and improve resilience are defined in various literature sources as either “climate-smart”, “sustainable” or “green” technologies and practices. A few of these technologies and practices are highlighted in Table 9.

Based on the information above, water smart agriculture (WSA) innovations have been defined as those technologies and practices that contribute to the principles of climate smart agriculture as defined by the Food and Agriculture organization of the United Nations (i.e. increased productivity and incomes, increased resilience and reduced greenhouse gas emissions) but in the context of this study aim to improve water use efficiency and productivity.

Table 9: List of climate smart agriculture innovations

Climate smart innovations	Description	Sources
Sustainable practices	The sustainable agriculture practices such as agro-ecology, organic farming, agroforestry and regenerative agriculture can increase agricultural productivity while contributing to a more climate resilient and sustainable form of food production. These practices all have principles and approaches that guide the food production process but ultimately aim to address the impacts of climate change by improving soil health and conserving natural ecosystem services. The practices improve water-use efficiency and productivity by reducing water evaporation from the soil.	D'Annolfo, Raffaele & Graeub, Benjamin & Gemmill-Herren, Barbara (2015) Ersek, 2019; Saunders and Hansen-Kuhn, 2020; Senyolo et al., 2017
Undercover farming technologies	Undercover farming technologies involves the growing of food under protection. These can range from low-to-medium tech systems such as shade nets and greenhouses which are fitted in open-field farming to more high-tech systems such as indoor farming technologies with controlled environment and growing methods (i.e. soilless growing methods such as hydroponics, aquaponics and aeroponic systems). The use of soilless growing mediums use between 80% and 95% less water than traditional farming.	ARC(2016); Visser et al., 2012;
Precision agriculture and smart farming	According to experts, the expansion of smart farming will result in increased production per crop, and more efficient production systems. Precision farming manifests in different farming types, including vertical farming, controlled (urban) environment agriculture, dairy farming and livestock farming. The agricultural sector uses sensor technology mainly to collect data on soil, crops and animals through integration into all kinds of equipment and machines, aircraft and drones or even satellites. Soil sensors can be integrated into the entire value chain in farming, supply chain or postharvest systems – from providing weather data to product processing. Applications of smart farming also include: • Remote sensing technologies and services become more relevant when considered in conjunction with water-management technologies. • Agricultural extension via digital advisory services which involves the use of smartphones to provide agronomic support to farmers through extension officers.	Aisenberg (2017); USB (2019)
Water saving irrigation technology	The amount of water applied in soils can affect the nutrient concentration in soils and the rate of nutrient uptake. The efficient irrigation technology feeds root system of crop by releasing water only when needed. It further reduces evaporation and limit water run-off, implying less/no chemicals go on groundwater table. Drip irrigation is a solution for farmers to reduce runoff and evaporation and prevent nutrients from washing away.	Popescu (2018); Senyolo et al. (2017)
Alternative water sources	The use of treated wastewater reuse or harvested water for agricultural irrigation.	Lochery(2017) ; Smakhtin et al. (2001)
Improved seed varieties	Seeds developed to tolerate drought, pests and diseases and subsequently mature early.	Senyolo et al. (2017); Sharma et al. (2015)

4.1.1. Trends in agriculture innovations

The agriculture sector is shifting away from traditional forms of farming and transitioning into more efficient and technology driven modes of food production. This shift is largely driven by the challenges currently experienced in the sector such as climate change, population growth and water scarcity. In addition, the fourth industrial revolution is changing the dynamics of the agriculture sector with regards to how food is produced, processed and traded. There is a growing trend towards the application of data-driven and Internet of Things (IoT) enabled smart technologies to produce food efficiently, safely and in a manner that is sustainable to the environment. The five major innovations emerging globally in the agriculture sector include:

- farm automation (i.e. automatic water and seeding robots),
- IoT sensors,
- indoor vertical farming,
- smart farming and,
- blockchain technologies (PlugandPlay, 2020; Smartcity, 2019).

4.1.2. Innovation trends in South Africa

The trends highlighted in the preceding section are similarly emerging in the South African context. However, due to the low cost and availability of labour, the uptake of automation technologies in the form of robotics is still quite low. The emerging innovation trends in South Africa involve the use of data analytics or (IoT) to improve efficiencies of farm operations and productivity; the application of intelligent irrigation technology (such as drip systems and soil water sensors) which is largely driven by recent drought conditions, vertical farming through growing in vertically stacked layers (A-frames), controlled environment agriculture, and mobile applications to monitor crops, water levels and provide increased access to markets.

A study conducted by the Stellenbosch University identified nine emerging water smart technologies and innovations in the Western Cape. The technologies were selected due to the drought experienced in the Western Cape and the role the water technologies can play in reducing the impacts of the drought. Given that South Africa has been experiencing water shortages since 2015, these technologies would be applicable across the country. The technologies were identified based on their affordability, geographic viability, user-friendliness, and perceived risks that they present to the society. These technologies are (USB, 2018):

- Remote sensing
- Smart monitoring of water
- Mobile phones for weather forecasts
- Seasonal hydrological forecasting
- Unmanned aerial vehicles (UAVs)
- Intelligent irrigation
- Solar power for irrigation
- Aquifer recharging

- Wastewater treatment technologies

Besides aquifer recharging and wastewater treatment technologies, these technologies are aligned with the innovations identified in this study. For the purpose of this study, five innovation clusters were identified based on the current uptake and the potential to improve water use efficiency and productivity. These include: irrigation systems, smart farming technologies, undercover farming systems, sustainable agriculture practices and drought tolerant crops (see Figure 20).

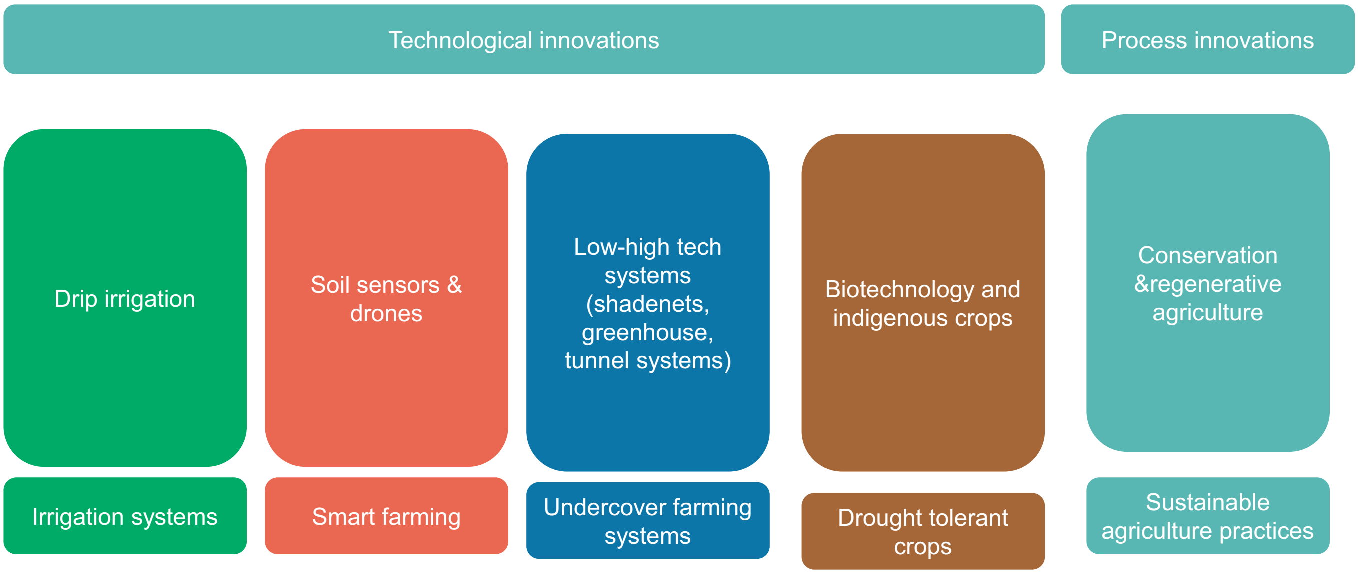

Figure 20: WSA innovation clusters and technologies

Technological and process innovations were identified in the different innovation clusters (as indicated in Figure 20). The technologies were selected based on the emergence of these innovations in the South African agricultural market and their potential for improved water efficiency and productivity. However, in understanding the market uptake and size of the WSA innovations, the market analysis only focused on the technological innovations because the main business opportunity in the adoption of these innovations is in the purchasing or leasing of the technology. While there may be consulting business opportunities with these technological innovations, these are likely to be limited in scale and not innovation specific. In addition, most companies that offer the technological innovations also include a service offering with the technology, which effectively couples the opportunities. Process innovations such as sustainable agriculture practices are further enabled by technological innovations.

4.2. Major drivers for WSA innovations

The major drivers for water smart agriculture innovations indicated in the relevant literature and further expanded in stakeholder interviews are shown in Figure 21. About ~45% of the total number of stakeholders interviewed (n= 33) noted climate change among the major drivers to the uptake of WSA innovations, while ~42% indicated rising input costs, and ~36% highlighted scarce natural resources as a key driver. Other drivers included population growth and water metering regulations.

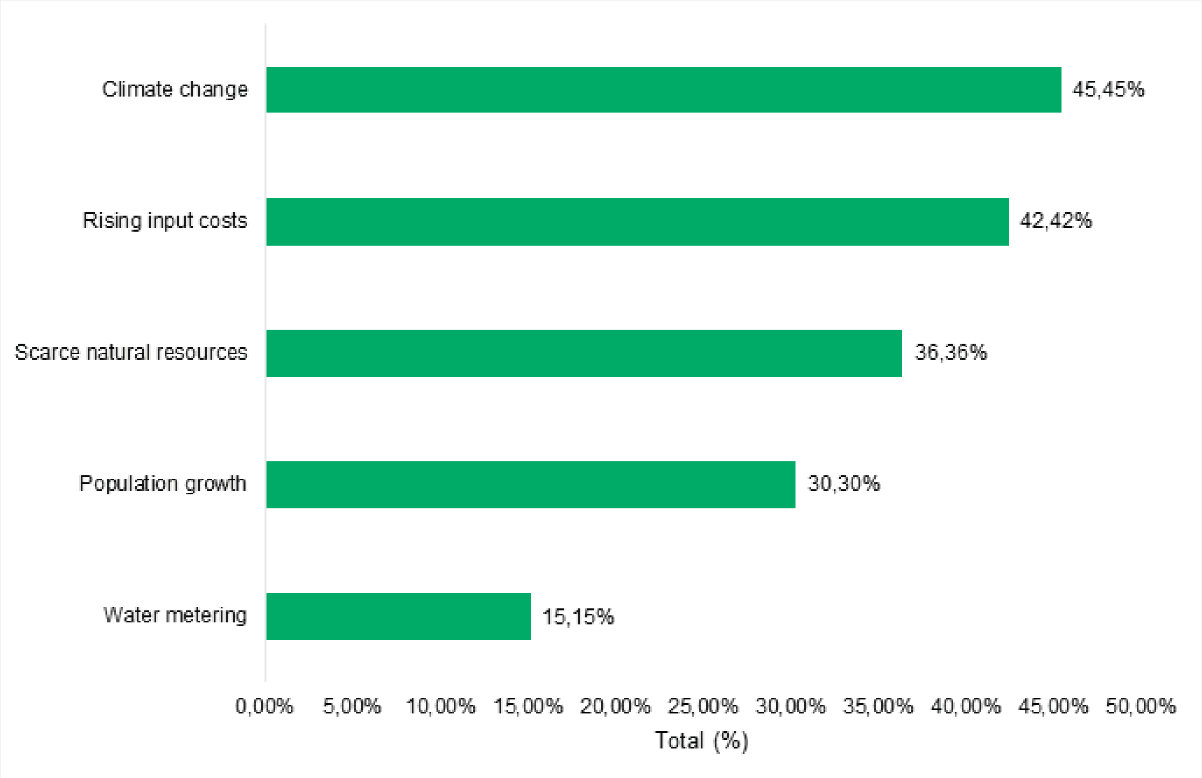

Figure 21: Drivers to the uptake of WSA innovations identified from stakeholder interviews (n=33)

- **Rising input costs.** The rising cost of inputs such as energy and fertilisers drive the need for producers to become more efficient in their agricultural activities. On irrigated farms, energy costs are high because of the energy used to pump irrigation water. With rising energy costs in South Africa, investing in water-efficient technology is important for the financial sustainability of farms.
- **Scarce natural resources.** Scarce natural resources, particularly productive land and water, limit agricultural production, which drives the need for farmers to increase their water use efficiency. Low and erratic rainfall, as well as limited arable land makes water the most limiting factor in agricultural production in South Africa.
- **Population growth**. The expected population growth will increase the demand for water, food and energy, resulting in increased competition for natural resources. Given the scarcity of natural resources, the increasing demand will drive a need for sustainable and efficient ways to intensively produce food. Additionally, consumer preferences are evolving and include more focus on health and wellness. While the traditional drivers for food purchases such as price, convenience, and taste still hold, there is a shift towards a wellness mind-set and interest in the transparency of food products. This drives a need for increased monitoring of farm operations and practices to provide access to the relevant information.
- **Climate change.** Variability in the climatic conditions has severe consequences on the production and quality of food resulting in negative economic

consequences. The effects of climate change have been felt across the country in the form of drought conditions, severe floods, and wildfires. It is anticipated that these impacts will continue in the long-term. The changes in the climate will have ramifications on the water demand for crops grown in both irrigated and rain-fed systems. The variations in seasonal rainfall and increased temperatures will increase the demand for water for evapotranspiration on crops and thus driving a need for efficient water systems.

- **Water metering.** All irrigation farmers are now required to accurately meter their water usage and report it to the Department of Human Settlements, Water and Sanitation. This necessitates increased monitoring and measuring of water-use on farms. In addition, this measure has shown to improve the management of water resources due to the increased awareness of water usage.

5. Market opportunities and demand analysis

This section provides a detailed analysis of water-smart agriculture innovations, outlining the market overview, the market drivers, the market size estimate, the barriers identified to the uptake of the innovations and the market growth opportunities.

5.1. Irrigation systems overview

The market for irrigation systems in South Africa has developed over the past century. The area under irrigation has shifted since 1945 from the traditional flood irrigation systems to application of sprinkle and micro irrigation systems and mobile systems emerging in the 1970s. The development of the different irrigation systems in terms of total area under irrigation from 1910 to 2020 is depicted in Figure 22.

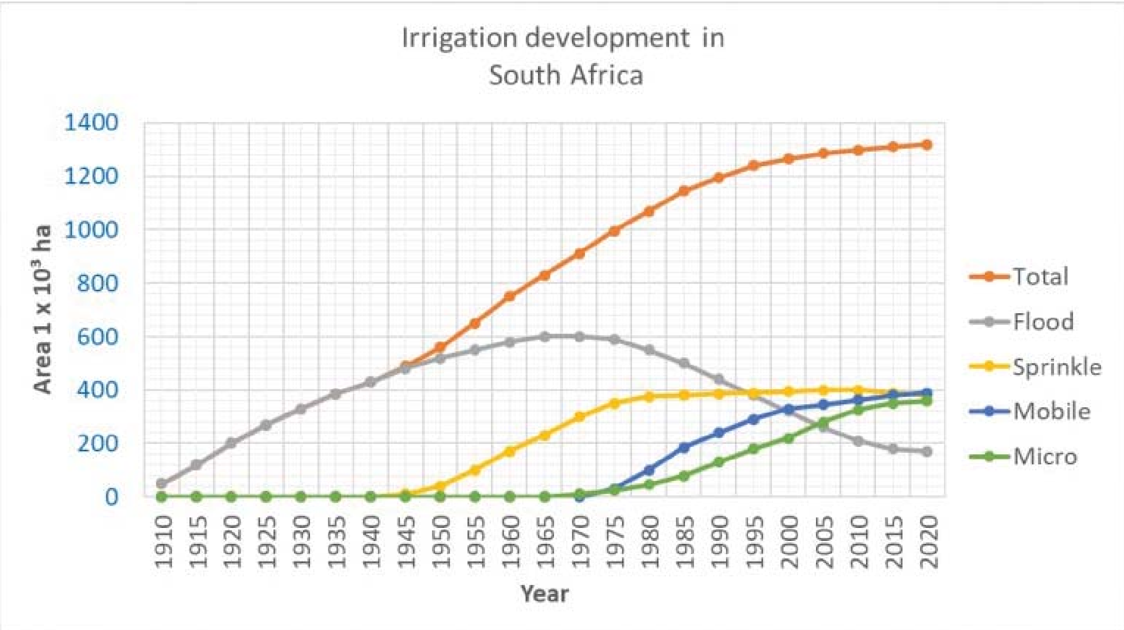

Figure 22: Irrigation development in South Africa (1910-2020*)* (Linda Botha, 2020)

The area under irrigation has increased steadily from ~ 810 000 ha in 1960 to ~1.3 million ha in 2020. In 2014, there were ~35 640 registered water users, of whom approximately 15 000 were medium to large-scale irrigators, while a further ~150 000 small-scale farmers practised irrigation (Bonthuys, 2018; Schulze, 2016a). The area registered by the Department of Water and Sanitation (DWS) in 2014 to be under irrigation showed an estimated (this can also be seen in Figure 22):

- 31% is sprinkler irrigation, made up of dragline, quick-coupling, permanent, hop-along, big gun, side roll and boom systems;
- 29% is moving or mobile systems irrigation, consisting of centre pivots, linear, sprinkler travelling guns and sprinkler travelling boom systems;
- 26% is micro irrigation, which includes micro sprinkler, micro spray, drip and subsurface systems, and which has increased significantly from < 12% in 1990; and

- 14% is flood irrigation, made up of furrow, border and basin irrigation (Schulze, 2016a).

The different type of irrigation systems vary based on the way the water is distributed in the field. According to Sauer (2010) the suitability of a particular irrigation method is determined by the crop-specific tolerance toward moisture, the characteristic planting and harvesting techniques, the specific physical habit of the crop, and its economic market value. However, given the water scarcity challenges there is an interest in more water efficient and productive technologies.

Table 10 shows the different irrigation systems in the South African market and their irrigation efficiencies[8]. Drip irrigation systems (subsurface and trickle) are the most water efficient, with an irrigation efficiency that ranges between 85% and 95% (further outlined in Table 10).

Table 10: Irrigation systems and efficiencies

Irrigation System	Efficiency (%)
Flood (border, drill)	45-60
Sprinklers – portable	60-70
Micro sprinklers	75-85
Drip (trickle)	85-90
Subsurface drip	90-95

Source: (Schulze, 2016)

Moreover, low-flow drip irrigation systems are emerging in the market. Low flow drip irrigation systems deliver water at a flow rate of 1l/hour or less which is lower than what has commonly been used with drippers delivering at rates of 4l/hour (AgriOrbit, 2020). The irrigation system saves water by irrigating only in the root zone and allowing for better soil-water-air ratio.

A farm can further improve irrigation efficiency by either improving on the type of irrigation system or enhancing the operations of the systems in place. Current farm operations can be enhanced by either adding systems such as irrigation scheduling software and sensor technology (discussed in section 5.2) that allows for improved decision making. Furthermore, renewable energy solutions can be integrated with irrigation systems to further reduce input costs. Examples of these include solar powered irrigation systems (SPIS) and variable speed drives (see box 1). These are innovations that feed into the water-energy-food nexus ecosystem by addressing water, energy and food challenges.

However, given that the water-use efficiency and productivity of the innovations noted in box 1 depend on the type of water pump or irrigation systems that is integrated, this market analysis explored the opportunity of the most water efficient

[8] Irrigation system efficiency refers to the percentage of water that will reach the soil surface. The percentage loss is usually caused by evaporation as the water droplets travel through the air. Losses will increase if air temperature is high and/or there is strong wind.

irrigation systems. As noted in Table 10, drip irrigation systems are the most irrigation efficient. Therefore, the sections that follow will focus on drip irrigation systems and their associated evolutions, i.e. surface, sub-surface and low-flow drip.

Box 1: Water-energy-food nexus innovations

Solar powered irrigation systems (SPIS) use photovoltaic (PV) cells to generate energy to pump water. The unreliable supply of electricity, the rapidly rising cost of electricity (the average standard Eskom tariffs have risen by almost 300% since 2007 as shown in Figure 23) and the greenhouse gas emissions from fossil fuel powered electricity are the major drivers to the uptake of solar PV in South Africa. Furthermore, the agriculture sector will be included in phase 2 of the carbon tax commencing in 2022. This will further drive the demand for cleaner sources of energy in the sector.

When solar PV is used to provide some or all of those energy requirements, the cost savings can be very significant over time, leading to higher profitability. Table 11 details the current levelised cost of electricity for solar PV installations. Comparing these costs to the Figure 23, the business case is clear. Once a solar PV system has been installed the asset has a useful life of more than 25 years (with minimal maintenance). This means that the costs per unit of electricity will remain constant for the next 25 years while the costs of grid electricity and the of using petrol or diesel to run generators will continue to rise (GreenCape, 2021). Given this, the market demand for solar PV is likely to penetrate to the irrigation sector.

Table 11: Solar PV costs in agricultural installations

System size (kWp)	Capital cost of system (R/kWp)	PPA tariff (LCOE)
< 100 kWp	R 12,000-R 15,000	0.90c-R 1.20
< 500 kWp	R 9000-R 13,000	0.80c-R 1.00
> 500 kWp	R 8,000-R 12,000	0.60c-0.90c

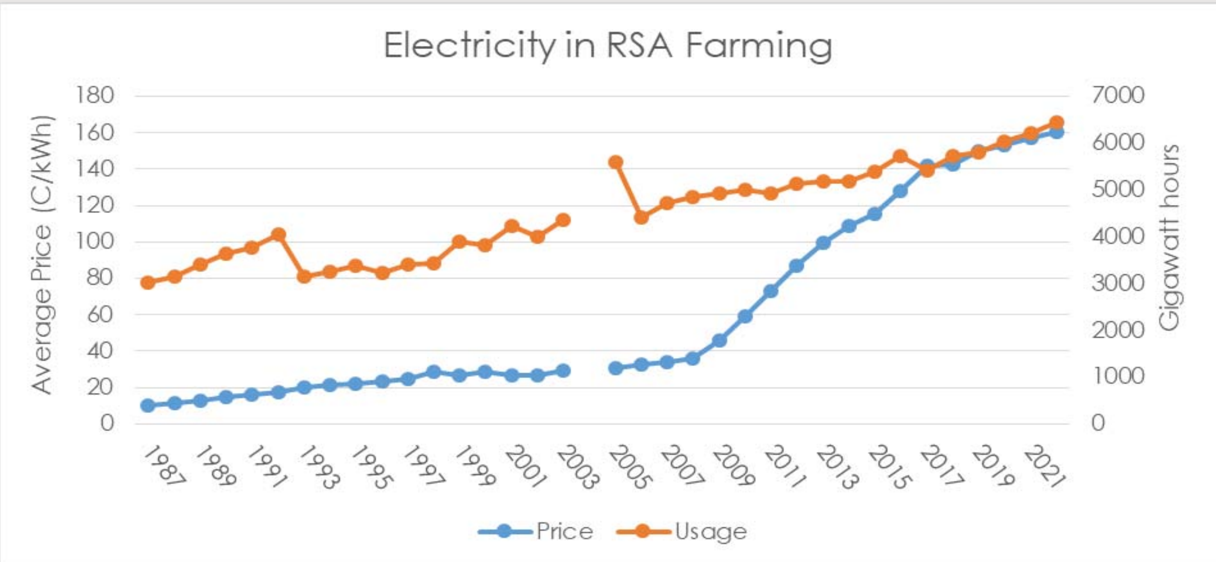

Figure 23: Electricity in SA farming (price vs demand) – (WCDoA, 2020)

The competitiveness of SPIS depends on the type of water delivery system, the crop type, and the cultivated area and how the systems compare to other forms of energy. A case study conducted in Ethiopia assessed the feasibility of solar water pumps for smallholder irrigation on different farm sizes ranging between 50 and 200 m^2, with different irrigation systems (i.e. drip, furrow and overhead) and three different crops (pepper, carrot and cabbage). In the case where solar pumps were used in combination with a drip irrigation technology, the system resulted in lower operational costs when compared to using a solar pump with furrow or overhead technology. The study showed that investments in smallholder irrigation were profitable and resource efficient when combined with drip irrigation system (Otoo et al., 2018).

Most installations of SPIS are taking place in arid regions in Sub-Saharan Africa, India and South America among. The major driver and enabler to uptake of SPIS in these regions has been subsidies from national governments and financing models such as lease-to-own, pay-as-you-go and bundled services. The uptake of SPIS in South Africa has been relatively low for both large and small-scale farmers. This is partly due to the high upfront cost of SPIS, but also that the business case for these systems is still unclear in South Africa. Although there is a strong business case for solar PV, there is further research required to understand the economic, environmental and technical feasibility of SPIS in South Africa, especially when considering the type of water delivery system integrated.

Variable speed drives or Variable Frequency drives (VFD) are motor driven technologies that can provide energy savings and reduce operating costs in a range of industries such as mining, agriculture or agroprocessing. The application of VFD in irrigation pumps allows for better control of water flow and pressure, saving electrical energy. South Africa is among the countries on the African continent showing growth in application of VFD, with the largest application seen in the industrial and commercial sectors. The growth of VFD have led to costs of VFD decreasing, however the technology is still relatively expensive. The high costs of the system coupled with technical skills and awareness limit the wide spread adoption of the VFDs (Du Plessis et al., 2013).

In cases where VFD have successfully been adopted for irrigation, the payback period ranged between 7 and 14 months and resulted in approximately 20-40% in energy savings. However, similar to SPIS the competiveness depends on the crop type, area irrigated and type of water pump.

5.1.1. Business case for drip irrigation systems

The major benefits of utilising drip irrigation systems are that they have the highest irrigation efficiency of all irrigation systems. The gains from the water use efficiency and savings in fertigation[9] from drip irrigation leads to substantial reductions in cultivation costs (Luhach et al., 2004; Misquitta & Thatte, 2018). Drip irrigation can also result in considerable savings in energy and labour (Linda Botha, 2020; Narayanamoorthy, 2016). Due to the high capital costs of installing drip irrigation systems, these systems are most realised in high value crops.

[9] Fertigation is a process that combines fertilization and irrigation. Fertilizer is added into an irrigation system.

The financial feasibility and cost estimates of the different irrigation systems have been well-researched. Most studies note that the economic feasibility of irrigation systems used depends on the type of crop irrigated, as it has implications on the fuel, labour, and water costs (Dhawan, 2000). In addition, the yields and prices of the crop determine the payback period for the irrigation investment. A research project carried out in Mpumalanga in the Onderberg region analysed the economics of the applied irrigation systems (micro-, drip- and furrow irrigation systems) (Oosthuizen & Meiring, 2005). The total annual fixed and operating costs estimated for drip-, micro- and furrow irrigation systems are displayed in Table 12. The cost estimates were based on crop water requirements for sugarcane under furrow irrigation systems and orchards (oranges) for micro and drip irrigation. The operating costs for furrow irrigation systems were high because of the water and labour use of the sugarcane crop. Drip irrigation systems had relatively lower fixed and operating costs compared to micro irrigation systems for orchards.

Table 12: Total annual costs of irrigation systems in Mpumalanga province

Summary of the total annual costs of a drip, micro and furrow irrigation system, the cost allocation, and the marginal factor cost, Onderberg area, Mpumalanga Province, 2002			
Irrigation System	**Drip**	**Micro**	**Furrow**
Total annual ownership/fixed cost (R)	28 509.87	39 817.10	17 763.61
Operating costs (R)			
Electricity	6 088.61	7 175.66	7 624.83
Water	24 938.70	28 340.97	67 535.14
Labour	1 884.55	1 131.65	29 600.14
Repairs and maintenance	4 045.52	2 331.77	1 615.43
Total operating costs (R)	36 957.38	38 980.05	106 375.54
Total annual fixed and operating costs (R)	65 467.25	78 797.15	124 139.15
Cost allocation per unit			
Fixed costs/ha (R)	1 147.50	1 598.77	352.45
Labour cost/m³ water pumped (R)	0.0106	0.0056	0.0613
Repairs and maintenance/m³ (R)	0.0227	0.0115	0.0033
Electricity costs/m³ (R)	0.0287	0.0306	0.0138
Water costs/m³ (R)	0.1398	0.1398	0.1398
Marginal factor cost of water applied (R/m³)	0.2018	0.1875	0.2182

Source: (Oosthuizen & Meiring, 2005)

Furthermore, Table 13 shows a comparison of the net present value, internal rate of return and pay-back period of fruit crops grown under furrow and drip irrigation methods in India. The costs of irrigation systems were recovered for both systems after seven years for the selected fruit crops. However, the net present values and internal rate of return for drip irrigation systems is higher compared to furrow irrigation systems. Drip irrigation systems were found to be more viable and cost-effective for the selected orchards compared to furrow irrigation (Luhach et al., 2004).

Table 13: Comparison of net present value, internal rate of return and pay-back period of fruit crops grown under furrow and drip irrigation methods in India

	Crop	Net present value (Rs)	Internal rate of return (IRR)	Pay-back period (years)
Furrow irrigation	Citrus	86310	14%	7
	Ber	37048	22%	7
	Grapes	31522	24%	7
Drip irrigation	Citrus	133839	17%	7
	Ber	69013	29%	7
	Grapes	98044	29%	7

Source: (Luhach et al., 2004)

5.1.2. Global market

Approximately 20% of the total arable land is under irrigation, accounting for 40% of the global agricultural production. According to a study conducted by Jägermeyr et al. (2015) the global distribution of irrigation systems at country level is largely dominated by surface and sprinkler irrigation. Surface irrigation is practiced on about 85% of irrigated crop land in the world. The global distribution of irrigation systems is shown in Figure 24. As depicted, drip irrigation systems have a fairly low distribution.

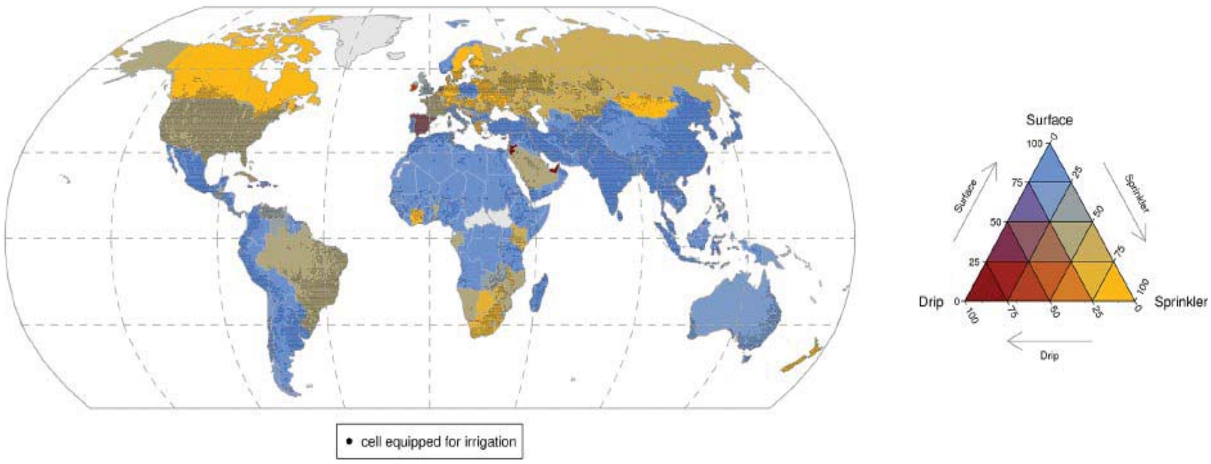

Figure 24: Global distribution of irrigation systems at country level based on AQUASTAT, based on (Jägermeyr et al., 2015)

The major countries practicing drip irrigation crop production are the United States of America (USA), China and India. China and India are among the key countries dominating the drip irrigation systems market due to their large agriculture sector, regional and export demand that are driving the need for drip irrigation systems. A range of high value crops are grown under drip irrigation such as field crops, vegetable and fruits and nuts.

The global market for drip irrigation systems is projected to grow from USD 5.5 billion in 2020 to USD 9.3 billion by 2025, at a CAGR of 10.8% (Marketsandmarkets, 2020).

5.1.3. South African market

This section provides an overview of the South African drip irrigation market, highlighting the markets trends by different technology types, farming type and commodity sub-sectors.

5.1.3.1. Drip irrigation market overview

The area irrigated under drip (surface) and subsurface irrigation systems were estimated at 150 000 ha and 27 000 ha respectively (Schulze, 2016c). This is shown in Figure 25, which provides a detailed breakdown of the different irrigation systems per annually irrigated area. Surface drip irrigation systems make up the third largest area irrigated after centre pivot and sprinkler dragline, while subsurface has the lowest area irrigated.

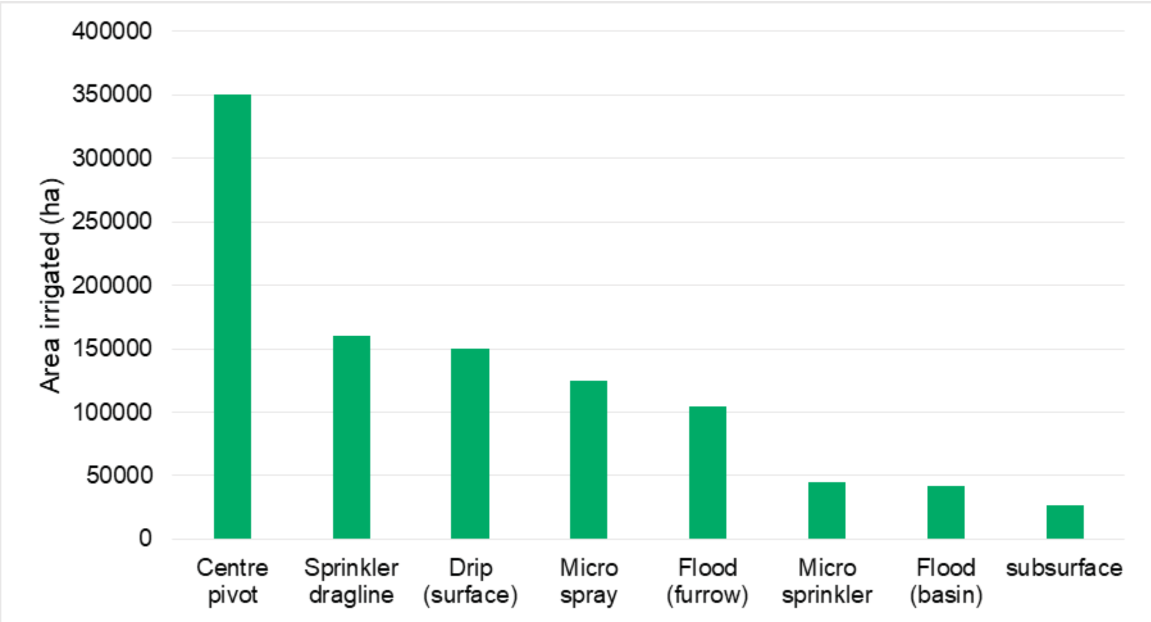

Figure 25: Detailed breakdown of irrigation systems per annually irrigated area (Schulze, 2014)

Low-flow drip is an emerging irrigation system in South Africa. The total area irrigated under the system is unknown and thus not presented in Figure 25. However, the system is increasingly being used in the nuts and avocado industries. This is further discussed in section 5.1.3.3.

5.1.3.2. Market trends by farm type

The uptake of drip irrigation systems has largely been among medium to large-scale commercial farms. The number of farms by type of irrigation system used have been determined in the census of commercial agriculture for 2017, these are shown in Table 14. Based on this data, drip irrigation systems are the most used systems on commercial farms accounting for 25.27% of the total number of farmers, followed by pivots (21,27%), and micro-irrigation (19,95%).

Table 14: Number of farms by type of irrigation system used for commercial crop production (Based on 2017 census)

Irrigation system	Number of farms	Percentage
Drip	1781	25,68%
Pivots	1475	21,27%
Micro-irrigation	1384	19,95%
Sprinkle	1371	19,77%
Dragline. Quick coupling lines	381	5,49%
Flood irrigation	300	4,33%
Canals	176	2,54%
Other	68	0,98%
Total	6936	

Source: (StatsSA, 2020)

In the case of smallholder farmers, the uptake of irrigation systems has been relatively low. Irrigation systems among smallholder farmers have largely been adopted through irrigation schemes[10]. The development of irrigation schemes dates back to the 1930s when South Africa was affected by severe drought and economic depression. Several large state schemes were developed with the intention of increasing food production, mitigating the risks of the drought, providing rural employment opportunities and establishing new farm enterprises. The schemes were developed at a time when South Africa's policies benefited the white minority, which meant that most of the irrigation schemes were established for white farmers. Irrigation plots for white farmers were 10 times larger than the plots allocated to black farmers. The small size (~1.5 ha) of irrigation plots allocated to black famers is the reason South Africa termed it "smallholder irrigation scheme", referring to the schemes on which land was held by black farmers (Van Averbeke et al., 2011).

According to Van Averbeke (2011) there were an estimated 302 smallholder irrigation schemes in South Africa in 2010 with a combined area of 47 667 ha. Of all 302 irrigation schemes, about 206 schemes were operational, 90 were not operational and the status of 6 schemes was unknown. The type of irrigation systems used in the schemes included gravity-fed surface irrigation, different forms of overhead irrigation, pump and sprinkler irrigation and micro irrigation systems. The number of operational and non-operational schemes by irrigation systems are shown in Figure 26. Most schemes used overhead and gravity-fed irrigation systems, pumped surface and micro irrigation systems were the least used. Of the total operational schemes (including unknown schemes), 37.5% operated overhead irrigation systems, while 22.6% operated gravity-fed schemes. Pumped surface and micro irrigation systems were comparatively low in the schemes, only 4.7% operated these systems

[10] An irrigation scheme refers to a shared distribution system for access to irrigation water and, in some cases, on a shared water storage or diversion facility (Van Averbeke, 2011).

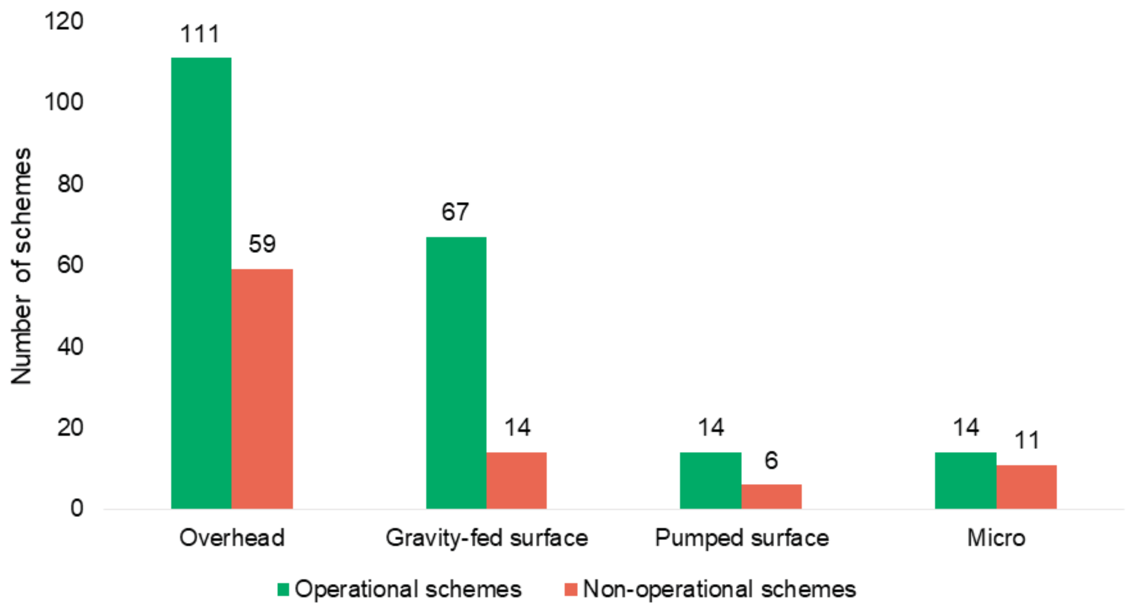

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Figure 26: Operational status of smallholder irrigation schemes by irrigation systems in 2010

The DALRRD developed a draft business plan in 2012 that aimed to revitalise smallholder irrigation schemes. Although it is argued that the revitalisation of these schemes could yield success in increased productivity of smallholder farms, most of the efforts in South Africa have so far seen little return (DALRRD, 2012b; Maepa et al., 2014). Pittock (2018) noted that smallholder irrigation schemes only function profitably and sustainably when there is substantial investment in the capacities of the farmers, their institutions and the formal and informal governing rules. Noting this, investments in drip irrigation systems could potentially increase productivity of smallholder farmers, given that the enabling environment and training is in place (further detailed in section 5.1.5).

5.1.3.3. Market trends by commodity sub-sector

Irrigation is estimated to be responsible for up to 90% of the production of high-value crops (i.e. vegetables, potatoes, grapes, fruit and tobacco) and about 25-40% of the production of industrial crops such as sugarcane and cotton (V. A. Niekerk, 2018). The registered[11] irrigation water users in 2014 operated ~61 960 fields, growing a wide range of crops, with maize, planted pastures, summer vegetables, lucerne and wheat each with over 100 000 ha under irrigation as shown in Figure 27 below (Schulze, 2016b).

[11] The 2014 statistic on the actual area under irrigation is equivalent to 87% of the registered irrigation area.

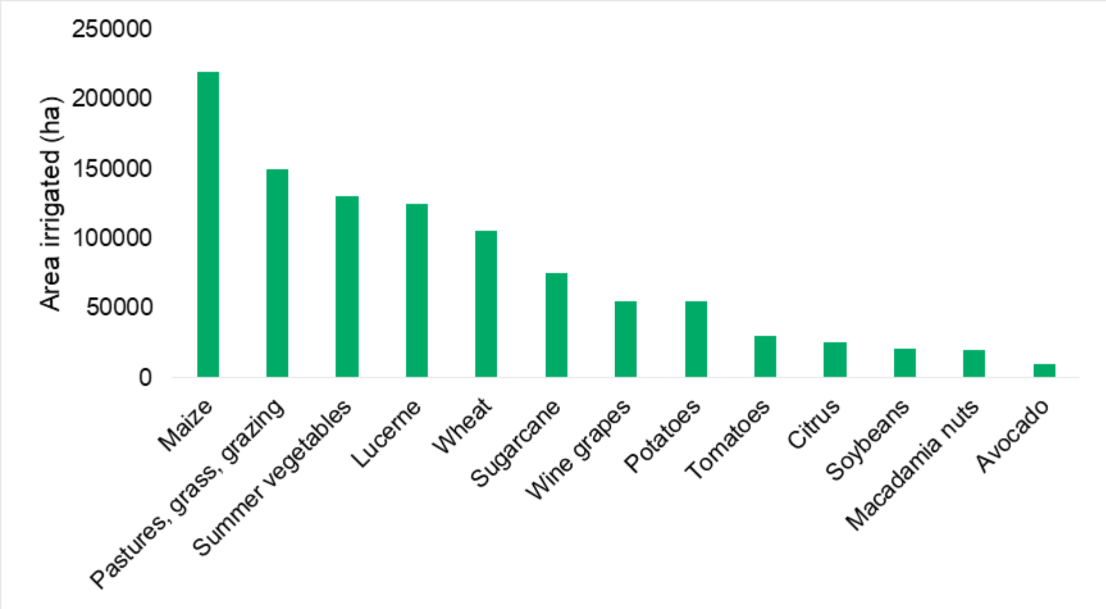

Figure 27: Top registered crop groups by area under irrigation (2014) (Schulze, 2016)

While the data is limited on the type of irrigation systems adopted by commodity sub-sectors, some of the agricultural commodities noted from stakeholder engagements and desktop research are shown below:

- **Surface drip irrigation**: The uptake of surface drip irrigation systems has been observed in the horticultural sector, particularly vines. The market for drip irrigation is close to saturation for wine grape production with ~80% uptake. The change in area under different irrigation systems in South African wine grape vineyards is shown in Figure 28. In the 1980s, large areas of dryland vineyards were converted to irrigation. Overhead irrigation systems were the most commonly used but declined in the early 1990s. While drip irrigation systems steadily increased from 1997 until 2015 (SAWIS, 2018).

  The growing change in irrigation systems to drip irrigation in the 1990s was due to several factors among which include: the deregulation of the wine industry, specialised financing to the wine industry from Nedbank, and increased awareness on the benefits of drip irrigation, which was enabled by extensive research conducted in the industry (Davidson et al., 2009). Furthermore, the introduction of the Integrated Production of Wine (IPW) scheme established in 1998 was a further driver to the uptake of drip irrigation systems. The IPW is a voluntary environmental sustainability scheme that was implemented by the wine industry and certifies wine producers that comply with international wine industry environmental sustainability criteria. The benefits of the certification result in increased marketing and export promotion of the industry.

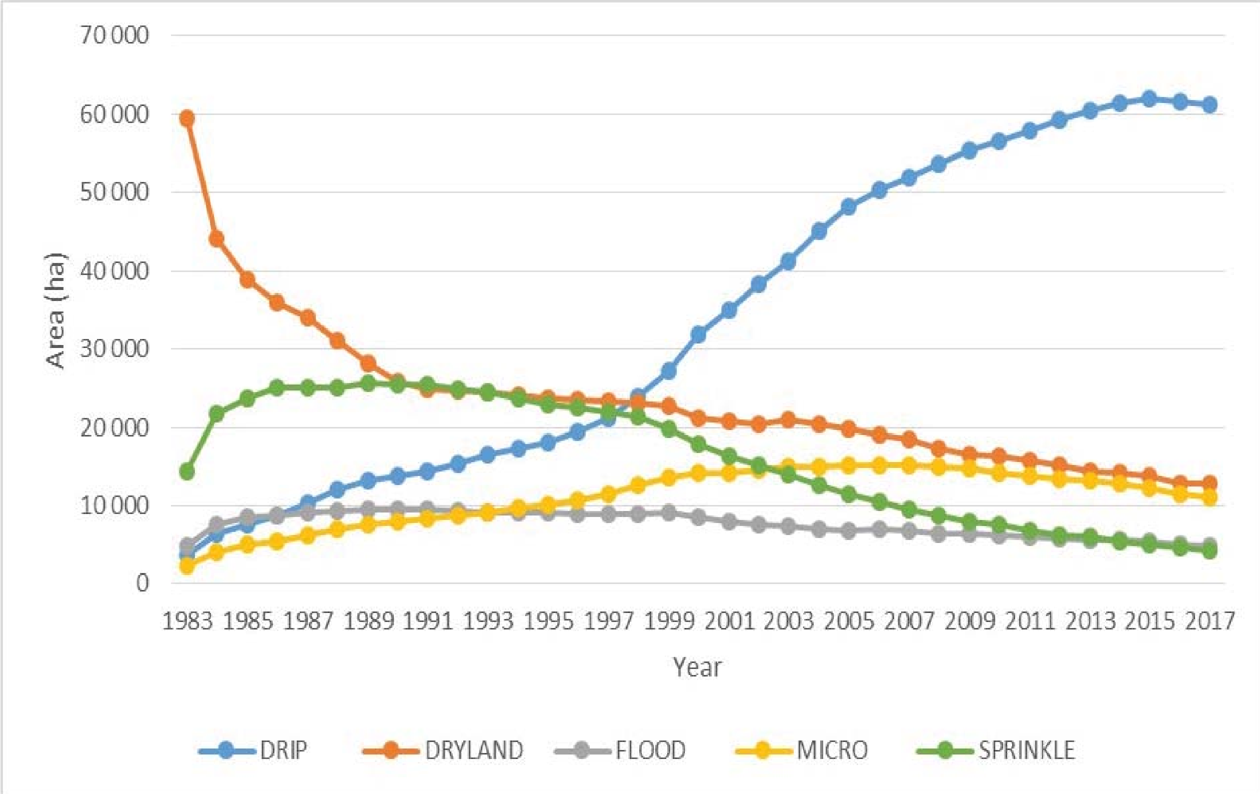

Figure 28: Change in irrigation systems used in South African wine grape farms (Adapted from SAWIS, 2018)

Further uptake of surface drip irrigation systems has been observed in cucumbers, peppers, and tomatoes.

- **Subsurface drip irrigation**: The uptake of subsurface drip irrigation has been mostly in grain and fodder production. There is no data on how much area is under subsurface drip irrigation for grains and fodder production. However, maize, which is an important grain in South Africa as a staple food (white maize) and feed grain (yellow maize), is largely produced under rain-fed conditions. About 5-15% of maize is under irrigation, the majority of which is reported to be produced under micro irrigation systems. Thus, the water efficiency gains from crops such as maize which are largely produced under rain-fed conditions, can be attained from either expansion of irrigated area and leveraging off the use of drip irrigation systems or through improved farm management practices (further discussed in section 5.4).
- **Low-flow drip irrigation**: The uptake of low-flow drip irrigation is quite nascent in South Africa. There is some evidence of the uptake of low-flow drip irrigation systems observed in the nut and avocado sectors.

5.1.4. Market barriers

While there has been some uptake of drip irrigation systems, there are major barriers that continue to inhibit the uptake of the systems. The noted barriers are highlighted in Table 15.

Table 15: Barriers to uptake of irrigation systems by farm type

<table>
<tr><th>Irrigation system</th><th colspan="2">Market barriers</th></tr>
<tr><td rowspan="5">Drip irrigation</td><td colspan="2">• High investment costs. Drip irrigation systems require high upfront investment, this limits the scaling of irrigation systems among a range of different farmers</td></tr>
<tr><td colspan="2">• Limited technical knowledge and skills to manage irrigation systems properly that result in inadequate implementation of irrigation scheduling methods.</td></tr>
<tr><td colspan="2">Barriers by farm type</td></tr>
<tr><td>Commercial farmers</td><td>Smallholder farmers</td></tr>
<tr><td>• High maintenance costs due to replacement of damaged irrigation equipment
• The return on investment is often too long (~7 years) to realise, especially in commodity sectors with low profit margins.
• Mindset shift to transition to a different system than the one typically used.</td><td>• Affordability. Most drip irrigation systems are too expensive for smallholder farmers.
• Poor performance of irrigation schemes. The factors that contributed to the poor performance of the smallholder schemes included poor maintenance of infrastructure and equipment; high energy costs where pumping was involved; lack of institutional support in terms of credit (only 5% of smallholders have access to credit); lack of extension and farmer training; and weak local organisation (Van Averbeke et al., 2011).</td></tr>
</table>

5.1.5. Market opportunity

This section highlights the market size estimate, the market drivers and the different factors that are likely to contribute to growth of drip irrigation systems.

5.1.5.1. Market size estimate

Given the market trends and uptake of drip irrigation highlighted in the previous section, the market size for drip irrigation systems was determined and is provided in this section. The market size calculation was based on the data available for the technology cost estimates (shown in Table 16).

Table 16: Capital and operating cost of drip irrigation systems

Innovation type	Annual irrigated area (ha) (2014)	Capital costs (R/ha)	Average cost (R/ha)	**CPI inflated cost (R/ha) (2019)	Annual maintenance costs (% of capital costs)	Data source
Surface irrigation	150000	10 000-12 000	11 000	13 415	30	ARC (2015)
Subsurface irrigation	27000	19 000-24 000	21 500	26 220	5	ARC (2015)
Low-flow irrigation	272*	59 000-100 000	79 500	79 500	NA	SABI; Farmers Weekly (2019)

*Based on data for irrigated area from the nuts and avocado industry (Linda Botha, 2020; SABI, 2019)

** CPI inflation rates from 2016-2019 only applicable for surface and subsurface drip irrigation

The formula used to calculate the market size is shown below:

Market size estimate = potential area under irrigation system x average capital cost of technology

The market size for drip irrigation systems can be derived from future projections for high growth crops and potential expansion of irrigated area. The NDP outlines a target to expand the area under irrigation by at least 500 000 ha by 2030 through better use of existing water resources and developing new water schemes. According to the BFAP baseline report for 2020, the total potential irrigated area might only need to be expanded by 145 000 ha by 2030 if there is a 10% efficiency gain on the existing irrigation area of about 1.3 million hectares. Recognising that the efficiency gain can be achieved from different water smart approaches and technologies which are provided in this study (i.e. sustainable agriculture practices, sensor technology or cultivation of drought tolerant crops), there is some potential for the efficiency gain to be attained from a conversion from inefficient irrigation systems to more efficient ones.

The market size was estimated on the basis that the efficiency gain of the existing irrigation area is attained from the conversion of inefficient irrigation systems to more efficient irrigation systems. The estimate was based on the change in irrigation systems in the wine grape sector (see Figure 28), where drip irrigation area increased at an average annual rate of 7.18% between 1995 and 2015. While overhead and flood irrigation area decreased at a rate of 7.35% and 0.87% respectively (SAWIS, 2018). The change from flood irrigation systems can also be seen broadly in Figure 21. Assuming that this trend is applied across commodities and that increasing area under drip irrigation systems is due to the change from inefficient systems, the total potential area for drip irrigation systems per year is conservatively estimated at ~44 000 ha. This is shown in Table 17.

Table 17: Market size for drip irrigation systems

Potential area for drip irrigation systems			
Less efficient systems (Sprinkle and flood)	600552,90		
Conversion rate p.a.[12]	7,18%		
Potential area for drip irrigation systems (ha) [13]	43103,76		
Potential expansion (ha)	946,10		
Total potential area for drip (ha)	44049,87		
Irrigation system	**Market readiness**	**Potential area (ha)** [14]	**Market size per year**
Surface	H	37273,11	R1,48 billion
Sub-surface	H	6166,98	R244,90 million
Low-flow	M	440,50	R17,49 million

5.1.5.2. Market drivers

In addition to the drivers mentioned in section 4.2, the market growth for irrigation systems is likely to be driven by the following factors:

- **Water policies** related to restrictions and water metering have added pressure to the agriculture industry to minimise water use. The National Water and Sanitation masterplan (2019) highlights a key action in the agriculture sector to reduce the total water use per unit production by 10% over a 10-year period. Thus, it drives a need for irrigation farmers to become more water efficient.
- **Revitalisation of irrigation schemes.** The DALRRD developed a business plan to revitalise smallholder irrigation schemes. The plan outlines a target to revitalise 2% of small-scale government irrigation schemes that amount to a total of 1000 ha between 2009 and 2014. To date, the focus on smallholder irrigation schemes has been towards the transfer of responsibility for management of irrigation schemes from government agencies to farmers or other non-government agencies. The revitalisation of smallholder irrigation schemes present opportunities to increase water-use efficiency in smallholder farming and increase crop yields with existing technologies.
- **Rehabilitation of mining land for agricultural production.** With the increasing number of mines closing, there is an interest in the use of rehabilitated mine for agricultural production. Several research institutions are exploring the viability and suitability of the soil and potential to either produce saline tolerant or energy crops on rehabilitated mining land. The growing interest in rehabilitation of mining

[12] Assumed that the growth in drip irrigation area in the wine sector (SAWIS, 2018) was attributed to a decline in irrigated area for inefficient systems only (i.e. excluding area expanded from non-irrigated areas) and that this trend is seen across all commodities.

[13] Based on the assumption that 7.18% of the potential area expanded (145 000 ha) will be under drip irrigation

[14] Based on the percentage of total potential drip area and assumed area based on current representation of drip systems (surface – 85% of total drip area, sub-surface – 14% and low-flow drip ~1%)

land for agriculture, presents an opportunity for integrating sustainable agriculture practices and utilisation of water smart technologies such as drip irrigation systems.

- The **African Continental Free Trade Agreement (AFCTA)** which came into effect on the 1st of January 2021**,** presents opportunities for increased competitiveness in the agriculture sector. The removal of tariffs on 90% of all the goods traded will open up markets for agricultural products, with increased market access to countries like Nigeria, Angola, and Senegal presenting opportunities for agricultural products such as oranges, bottled wine and apples (Morokong et al., 2021). The new markets and demand for these high value crops may increase their production and therefore the adoption of drip irrigation systems.

5.1.5.3. Market growth potential

Citrus: The area irrigated under citrus production Due to the high capital costs associated with the installation of drip irrigation systems, these systems are typically realised in high value crops. Therefore, the market growth potential for drip irrigation systems is likely to be a factor of growing demand for high value crops and increasing area under production. The growth of the crops projected in the BFAP (2020) report for the period 2019 to 2029 is detailed below:

- covers about 73 750 ha. Further expansion of the area under citrus is projected to slow over the next 10 years due to stabilising prices across all citrus types. The total area under production is expected to grow by 1.25% on average over the next 10 years. Of all the citrus types, only grapefruit is expected to show a positive trend in cultivation area, due to saturation of soft citrus, lemon and lime in the markets.
- Avocado: The avocado industry is showing a rapid growth, with the area under production increasing from 13 000 ha in 2010 to 19 000 ha in 2019 with new plantings estimated at 1000 ha per annum (BFAP, 2020; Donkin, 2020). Further growth in hectares in the industry is projected over the period of 2019 to 2029.
- Macadamia nuts: There is a growing demand for macadamia nuts. There were approximately 44 775 ha of macadamia nuts planted in 2019, the rate of production is expected to increase in the near future due to new plantings, increasing at about 2000 ha per annum (see Figure 29).

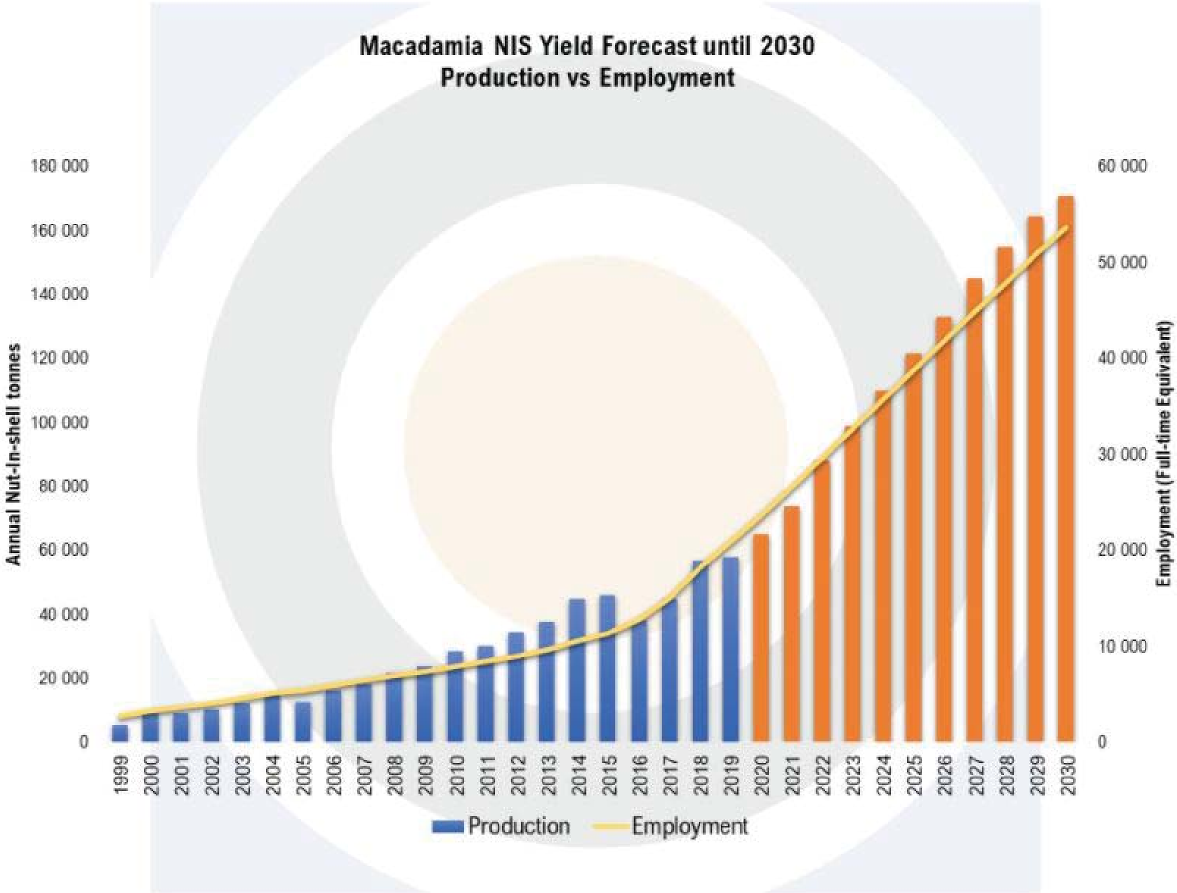

Figure 29: Macadamia production and employment forecast in South Africa until 2030 (SAMAC, 2020)

- Soybeans & yellow maize – the area under yellow maize and soybean is expected to increase by 9% and 47% respectively over the period 2019 to 2029.
- Barley and canola – increased expansion in hectares projected to reach 117 000 ha and 91 000 ha respectively by 2029.

As highlighted, the market for drip irrigation systems is concentrated in capital intensive farming industries, which are medium to large-scale commercial farms. The market opportunity for emerging commercial farms is still quite high. The irrigation systems used in smallholder irrigation schemes were largely overhead systems which have an irrigation efficiency of 60-70%. The literature on micro-irrigation systems (which includes drip irrigation systems) for smallholder farmers notes that with proper training and infrastructure, micro-irrigation could be implemented successfully on different scales of smallholder farms (Du Plessis et al., 2002). Therefore, there is an opportunity for all the different irrigation systems to be scaled in emerging farming markets. However, the scaling of these innovations would need to account for the barriers that inhibit adoption among emerging farmers.

In terms of the market opportunity for the different drip irrigation systems, the emerging nature of low-flow drip irrigation still holds a high market growth potential across a range of high value commodities. While surface and sub-surface drip irrigation have been adopted in some commodity sub-sectors (horticulture, grains and fodder production), the projected growth of high value crops and expansion of area under production noted in the previous section continue to present an opportunity for these systems. Given the market size and potential growth for drip irrigation systems, a market opportunity map[15] for the irrigation systems is shown in Figure 30.

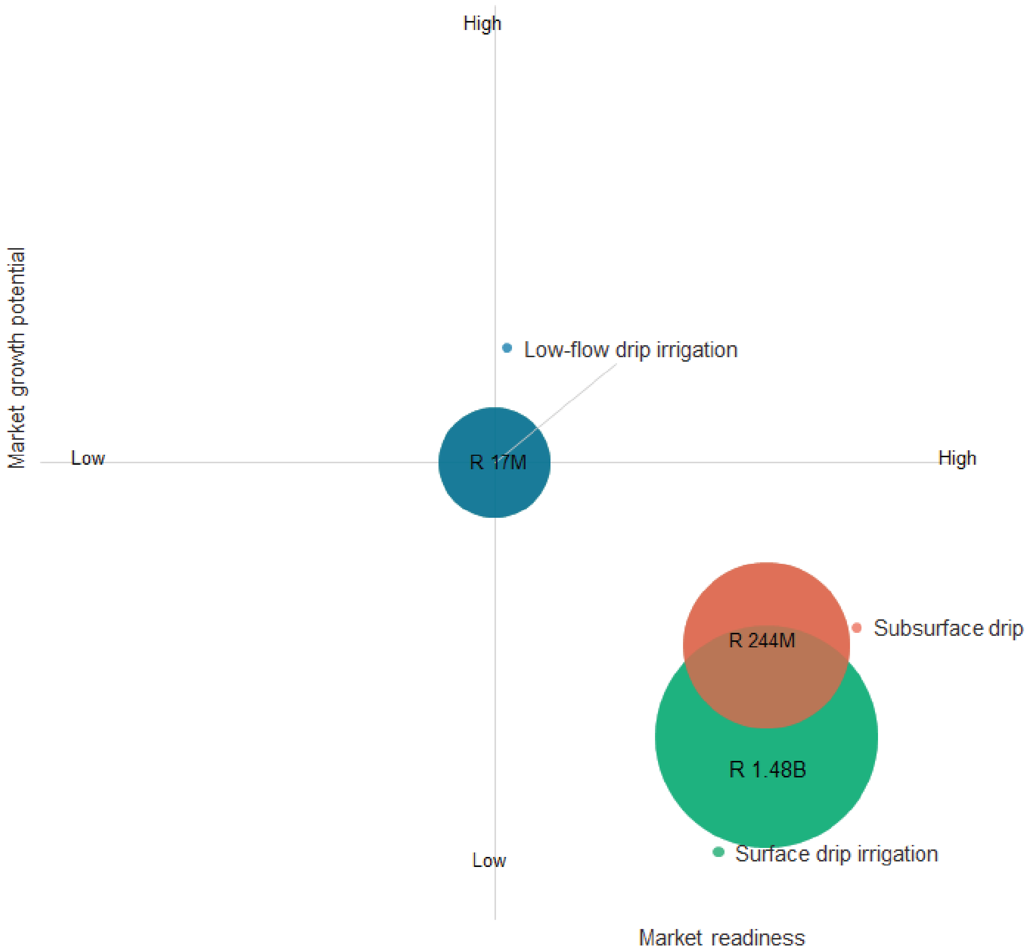

Figure 30: Market opportunity map for irrigation systems

5.2. Smart Farming

Smart Farming, also called 'precision agriculture', 'satellite farming' or 'site-specific crop management', enables producers to accurately apply inputs such as water, fertilizer and pesticides through various Smart Technologies, such as sensors,

[15] The market opportunity map shows the market for the irrigation systems and market growth potential ranked as either high, medium or low. The size of the bubbles represents the market size of the technology

Internet of Things (IoT), software solutions and robotics/ autonomous vehicles. Precision agriculture allows for automated field and processing operations, artificial intelligence and soil sensors that improve productivity and efficiency on farms. The broader categories of precision or smart farming technologies include a hardware and software component. The three categories include:

- Sensor technology: Real-time sensing systems which can include yield sensors or monitors, soil sensor to predict the soil organic matter and moisture, field sensors which can include drones and satellite imaging and anomaly sensors which can detect weed-infested zones
- Controls: The controls include variable rate technology (VRT) such as agrochemical applicators that allows farmers to apply the exact quantity of inputs at a specific location in the field and automated guidance systems can position moving vehicles.
- Software: The information gathered from precision agriculture technologies is evaluated and analysed to aid with decision making on farms.

The different components of smart farming are illustrated in Figure 31. In the context of this market analysis, the different smart farming technologies applied in South Africa will be explored, however the market opportunity will only focus on water-related smart farming technologies such as hardware and software technologies that improve water-use efficiency such as remote sensing technologies (drones and sensors) and services.

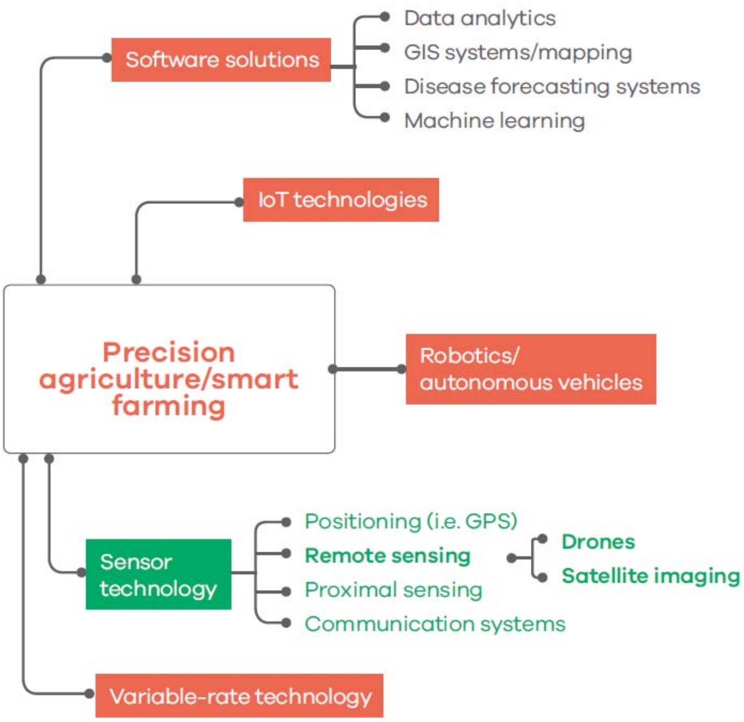

Figure 31: Aspects of precision agriculture and smart farming (USB, 2018)

5.2.1. Business case for smart farming

Smart farming technologies can help farmers to increase crop yields and reduce production costs while minimising environmental impacts. Examples show that farmers in the US have improved farm productivity due to smart farming techniques, producing an average of 7340 kilograms of cereal per hectare of farmland versus the worldwide average of 3851 kilograms per hectare (Telesense, 2017).

The data on the economic impacts of smart farming technology is limited. However, studies conducted on the impact of precision agriculture on profitability show that adoption of precision agriculture technology is positively associated with higher profitability (Castle, 2016; Schimmelpfennig, 2016). A study conducted in Swartland exploring the cost implications of technology options for winter cereal production noted the profitability of precision technologies. A key finding from the study was that precision agriculture production systems had high profitability compared to conventional production methods. The internal rate of return was determined at 5.83% which is an increase of 2.26% compared to conventional production systems and the NPV increased by 69% as shown in Table 18 (Bruce, 2017)

Table 18: Internal rate of return and Net present value for conventional and precision agriculture systems

System	Profitability indicators		Relative change
Conventional	IRR	3.47%	0%
	NPV	R16.27 million	0%
Precision	IRR	5.83%	68%
	NPV	R27.55 million	69%

Source: (Bruce, 2017)

Furthermore, the Western Cape Department of Agriculture (WCDoA) in collaboration with eLeaf launched an open access platform that collects remote-sensing data on vineyards and orchards in the Western Cape. The platform, Fruitlook, provides real-time data on crop growth, crop water use and nitrogen content. According to estimates conducted by WCDoA the use of Fruitlook translates into a 10% saving of input costs together with a 10% increase in production which yields earnings of about R33 860 more per hectare for table grapes and R25 630 per hectare for deciduous fruit (Bonthuys, 2016). In the case of drone application, experts in the Western Cape note reduced input costs and better margins from the use of drones on farms. A farmer from Laingsburg noted savings worth R20 000 in diesel from the use of drones to check water points (USB, 2018).

In the North West province, farmers that adopted precision agriculture techniques highlighted that it made economic sense and observed a pack-back period of about two years (Jacobs et al., 2018).

5.2.2. Global market

Precision agriculture is advancing across the globe at different levels. The United States was among the early adopters of precision agriculture and there are several national and regional networks and policies that support precision agriculture. In

Israel, the market for agricultural technologies is rapidly growing. The growth of the market can be attributed to increased government spending in research and development of which a large portion is dedicated to agriculture. Precision agriculture in Israel is led by modern water management programs that enable technical development and applications. Moreover, countries across Europe such as the United Kingdom, Germany and the Netherlands have industrial development programs that aim to digitise agriculture (Huang & Brown, 2018). A 2016 report by Internet of Things (IoT) Analytics estimated that 6% of IoT solutions was already being used on farms globally. Another report by Business Insider Intelligence projected that by 2034, the average farm would be generating 4.1 million data points daily generated from cell phones (Phillips, 2020). Therefore, there is a growing global interest in the application of precision agriculture technologies.

According to Estopace (2019) less than 2% of agricultural land worldwide is equipped for soil-moisture measurement, which presents a large market for soil monitoring and opportunity for improved water conservation. The global market for IoT sensors is projected to grow from USD 10.38 billion in 2020 to USD 19.51 billion by 2023, at a CAGR of 23.39% (Businessresearchcompany, 2020).

5.2.3. South African market

5.2.3.1. Smart farming market overview

Smart farming has evolved over the years from the use of geospatial technologies such as satellite imagery to the use of big data, drones and automation technologies. Advanced smart farming technologies are emerging in South African agriculture in-field sensors, and drones. A study conducted by Hendriks (2011) showed that 52% of summer grain producing farmers in North West and Free State provinces practiced precision agriculture. The most used precision agriculture technologies by summer crop producing farmers surveyed are grid sampling, yield monitors, and auto steer (see Table 19). The adoption rate of mobile soil sensors which are key technologies for water-use efficiency was quite low.

Table 19: Use of precision farming technologies by summer-crop producing farmers in South Africa

Precision agriculture technology	Percentage of farmers using technology
Grid sampling	79%
Planter monitors	43%
VRT planting	1%
VRT fertilizer	23%
VRT pest control	3%
Yield monitors	56%
Mobile soil sensors	7%

Precision agriculture technology	Percentage of farmers using technology
Auto steer	40%
Geographic information systems (GIS)	39%
Precision agriculture software	36%

Source: Hendriks (2011)

There is a growing interest in sensor technology and data analysis services. The combined use of hardware and software solutions provide farmers with information on farm operations. Several companies that offer such solutions use satellite derived data from in-field sensors and interpret results for improved farm decision making and efficiency. The combined use of hardware and software has been observed in the drone industry in South Africa, which has seen a significant uptake among commercial farmers.

Box 2: Decision support tools

In addition to remote sensing technologies, there is a growing number of decision support tools that guide farmers with long and short term irrigation infrastructure decisions. Farmers can learn how to improve crop yields through better management of irrigation water, soil nutrients and salinity levels. A few examples of these tools in South Africa include:

Virtual irrigation academy (VIA) – A suite of monitoring tools that collects data through mobile phones and displays the information in colour patterns on the VIA platform. The tool provides farmers information that helps to guide with improved water use. The tool has been applied in a range of different farms in South Africa and across Africa. A few examples of these include an onion farm in the Western Cape, a sugarcane farm in Mpumalanga and maize farms in the North West.

University of Cape Town's decision support tool to enhance adaption and farming enterprises. The tool aims to enable forecasting of rainfall and temperature for adaptation of farming practices to climate variability.

Stellenbosch University salt accumulation and waterlogging monitoring system. The decision support tool provides better management and identification of zones within fields and orchards which are affected by salt accumulation or waterlogging, allowing for more efficient mitigation measures.

Source: (Sishuba, 2017; WRC, 2020)

5.2.3.2. Market trends by farm type

The market for precision agriculture technologies has largely been targeted at medium to large-scale commercial farms and capital intensive farms that can afford the technology and services. According to a study conducted by the Inter-American Development Bank (IDB), the use of drones and satellite technologies show financial benefits when used on farms exceeding 40 ha and 50 ha, respectively (IDB, 2018). Thus, farms with a cultivation area less than 40 ha become unviable for drone usage. This was observed among farmers surveyed in the Schweizer-Reneke region in the North West province. About 39% of the farmers that cultivated on areas less than 500 ha did not adopt precision agriculture, while farmers cultivating on areas larger than 3000 ha (~34%) all adopted precision agriculture[16]. Farms that cultivated on areas between more 500 ha and less than 3000 ha had some or no adoption of precision agriculture (Jacobs et al., 2018).

The uptake of most precision agriculture technologies has been fairly low among smallholder farmers, mainly because most farmers farm on plot sizes that are less than 10 ha. The precision agriculture technologies that have been applicable and used by smallholder farmers are agriculture based apps, Internet of Things (IoT), and data analytics. Some examples include the digital solutions from Mezzanineware and Agritechnovation called MyFarmWeb, which is a cloud-based web platform that allows a producer to capture agricultural information, from the soil to the market, into a system that aggregates and calibrates the data to assist in best practice decision making. Producers can use the system to measure and record data ranging from soil physical, chemical, and microbial analysis, pest presence, satellite and remote sensing information and data from various internet connected farming sensors like soil moisture probes, vehicle trackers and weather stations.The solution is both on mobile and web-based. More than 2700 farms in South Africa are using the platform.

Other precision agriculture solutions that are used by smallholder and small-scale farmers are sensors that are integrated in greenhouse systems to monitor water conditions, temperature and pH levels. A detailed discussion on the greenhouse systems is provided in section 5.3.

5.2.3.3. Market trends by commodity sub-sector

Precision agriculture can be applied across all crop types. The largest uptake in area covered has been seen in the fruits, nuts, grains and wine industry through Fruitlook. Fruitlook is freely available to commercial and smallholder irrigation farmers in the Western Cape. Since 2014, the area covered has increased at an average annual growth rate of 49%, increasing from 15 509 ha to 76 211 ha as shown in Table 20 (WCDoA, 2019a). The increasing area was attributed to a range of factors, such as training initiatives, awareness of the tool, and pressure from the drought and website functionality. The crops covered by Fruitlook in the 2018/2019 season are depicted in Figure 32. A range of different crops were covered in the season. The largest area covered was under grain production, followed by wine grapes and pome fruit.

[16] The precision agriculture methods addressed in the study included auto steering, software and variable rate technologies

Table 20: Uptake of Fruitlook over time (2014-2019)

Year	Actual coverage[17] (ha)	Potential coverage[18]	% Used
2014/15	15 609	167 626	9,3%
2015/16	26 954	171 000	15,8%
2016/17	37 663	182 606	20,6%
2017/18	50 468	194 445	26,0%
2018/19	76 211	1 591 958	4,8%

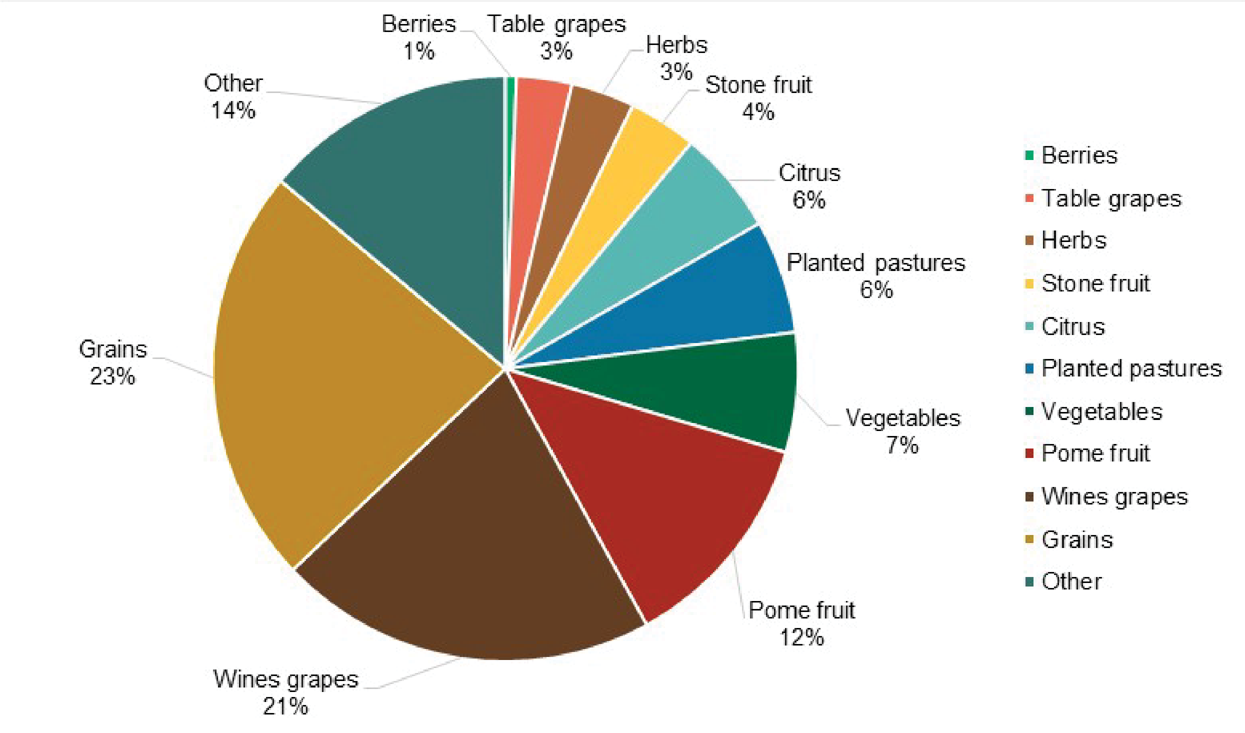

Figure 32: Crops under Fruitlook coverage in 2018/19 season (WCDoA, 2019a)

Commercial farmers are also investing in soil moisture monitoring technologies to guide irrigation scheduling of their crops. Several institutions across the country are developing decision support tools that can further guide farmers with better irrigation scheduling and water management (see box 2).

5.2.4. Market barriers

Due to the high uptake of remote sensing technologies among medium-large scale commercial farmers, the barriers to the uptake of smart farming have largely been observed among this farming type. The barriers to the uptake of smart farming by farm type are noted in Table 21.

[17] Actual coverage refers to the area ordered on Fruitlook in a given season
[18] Potential coverage refers to the total area available on Fruitlook

Table 21: Barriers to the uptake of smart farming

<table>
<tr><th>Technology</th><th>Commercial farmers</th><th>Smallholder farmers</th></tr>
<tr><td>Drones</td><td>Regulations on drone licensing. A drone license is required to operate a drone commercially in South Africa. Stakeholders alluded to the lengthy process to obtaining a license and the high cost associated. It can cost close to R100 000 on average[19] to obtain a license. Thus limiting entry into the market</td><td rowspan="2">There are barriers linked to affordability of innovations, access to inputs and lack of information.
Poor digital literacy
There is reliance on extension officers to provide support on farm management and often there are limited number of officers and resources, which limits farmers access to information
Internet connectivity. A key reason for low uptake of smart farming technologies is due to limited internet connectivity and high costs associated with internet connectivity. Although, mobile phone ownership in South Africa is up to 85%, only 47% have access to smartphones due to high costs associated with internet enabled phones (Aguera et al., 2020).</td></tr>
<tr><td>Sensor technology and services</td><td>Skills and knowledge gap. There is a lack of local skills and knowledge, especially technical skills in the development of smart farming technologies. This can result
Cost. The cost[20] of purchasing new technology and having to change existing infrastructure for efficiency gains have been noted as a key barrier for adoption among South African farmers. For farmers where monetary cost is not an issue, the time spent setting up their farms is costly. In the case of Fruitlook, farmers opted out of using the platform because of the above-mentioned barrier and the time required to interpret and apply the information. The delay in the information received has also been a drawback for farmers.
Value of information to farmers. Another key barrier to the uptake of smart farming technologies is the amount of information[21] that farmers consider useful to them. Farmers are unlikely to use different technologies that will provide the same decision-making process and having information from different technologies is time consuming and impractical. Farmers are noted to only use new innovative technologies if it links to their existing technology.
Lack of awareness on the type of technology available and the potential benefits available</td></tr>
</table>

5.2.5. Market opportunity

This section highlights the market size, market drivers and the different factors that are likely to contribute to growth of smart farming systems.

[19] Based on https://africandrone.org/south-africa
[20] Based on (Petrus De Clercq & De Witt, 2020)
[21] Based on (Petrus De Clercq & De Witt, 2020)

5.2.5.1. Market size estimate

The cost of service for use of remote sensing varies depending on the technology provider and the size of area monitored. The proposed cost of service for data collected through Fruitlook is estimated at R150/ha per season (Bonthuys, 2016). The cost can range from R150-R20 000 per month[22] depending on the number of hectares. Based on the cost estimate on Fruitlook and hectares covered in the 2018/19 season, the market uptake for remote sensing was determined. Additionally, Fruitlook conducted a survey among users to determine which other irrigation management tools were used next to Fruitlook. About 67% of the users noted that they use soil moisture probes for irrigation scheduling. This information, together with the area covered by Fruitlook in the 2018/19 season and cost of soil sensors was used to estimate the current market size. The cost of soil sensors can be between R10 000 and R12 000 per irrigation block[23]. The formula used to determine the market size is noted below.

Market size estimate = potential area x cost of service/technology

The market size for remote sensing technologies is outlined in Table 22. Due to limited data on the area covered in the rest of South Africa, the market size is reflective of the current uptake in the Western Cape based on Fruitlook and summer grain producing areas in the North West and Free State provinces. Although, remote sensing service is currently freely available for farmers in the Western Cape, the market size notes the serviceable area for remote sensing applications. The estimated market for remote sensing services is R459 million and R2.89 billion for soil sensors. Additionally, the drone industry was valued at R2 billion in 2017 (Steenhof-Snethlage, 2018).

[22] Based on https://swiftgeospatial.solutions/quote
[23] Data provided from interviews

Table 22: Market size and readiness level for smart farming technologies

Innovation type	Readiness level	Market uptake	Actual coverage[24] (ha) (2018/19)	Area under production (ha) (2018/19)[25]	Potential area	Market size[26]
Remote sensing services	M-H	Western Cape[27]	76 211	1 591 958	1 515 747	R227 million
		Summer grain producing areas (North West & Free State)[28]	1 072 520	2 615 902	1 342 382	R232 million
		Total	1 148 731	4 207 860	3 059 129	R459 million
	Readiness level	**Market uptake**	**Actual coverage (ha) (2018/19)**	**Potential area[29]**	**Potential irrigation blocks covered[30]**	**Market size[31]**
Soil sensors (hardware)	M	Western Cape[32]	51 061	1 540 897	102 726	R1.13 billion
		Summer grain producing areas (North West & Free State)[33]	209 272	2 406 630	160 442	R1.76 billion
		Total	260 334	3 947 527	263 168	R 2.89 billion
Drones	M					R 2 billion (2017)

[24] The actual coverage refers to the area that is currently under remote sensing (i.e. area ordered by farmers), while, potential area refers to the actual area available for Fruitlook coverage.
[25] Based on potential area for covered by Fruitlook in 2018/19 season (WCDoA, 2019) and planted area under summer grains in North West and Free State (SAGIS, 2019)
[26] Based on potential area and average cost of service (R150 per season for Fruitlook)
[27] Based on area under Fruitlook
[28] Based on adoption of precision agriculture technologies (see Table 19) and increase in area planted (~5.72% increase between 2011 and 2019). It was assumed that the actual coverage under GIS was 41% of the total area under summer crops planted (based on GIS adoption rate ~39% and assuming a 2% uptake from increased area planted).
[29] Determined by subtracting area currently covered and area under production.
[30] Average irrigation block ~15 ha (based on Fruitlook, 2019)
[31] Based on potential irrigation blocks and average cost of soil sensors (R11 000)
[32] Based on Fruitlook survey were 67% of the users noted that they use soil moisture probes
[33] Based on adoption of mobile sensors (~7%) and increasing area planted under summer grains in North West and Free State provinces). It was assumed that the total coverage for soil sensors was 8% (based on sensor adoption rate and assumed 1% uptake from increased area planted given the emerging nature of soil sensors).

5.2.5.2. Market drivers

The major drivers to growth of smart farming technologies are summarised below.

- **Increasing farm operations**. The increasing area under production and size of farm operations makes it complex to manage farms. Thus, remote sensing and automated technologies become critical to optimising farm operations. Farmers are able to efficiently monitor and assess activities on their farms such as irrigation schedules and crop health through the use of smart farming technologies.
- **International food standards and regulations**. There is a greater need for increased transparency in the food supply chain. Farmers producing for the export market need to adhere to stringent requirements to meet the food safety standards and quality. Additionally, there is a growing demand from consumers for increased transparency in the food supply chain. This drives the need for increased data collection on farm operations.
- **Affordable technology**. The costs of smart technologies and agricultural equipment are becoming cheaper with greater entry of new devices into the market.
- **Water scarcity**. The limited water resources drives a need for efficient use of natural resources.

5.2.5.3. Market growth potential

According to the study conducted by Accenture and the World Economic Forum (2020), the adoption of digital technologies could result in the creation of new jobs. The study notes that the potential value of digital technologies for the South African agriculture sector and society is estimated at R671 billion between 2017 and 2026 (as shown in Table 23). The value is determined based on a 'value at stake' framework that accounts for the value to society, consumers and the industry (Dawson & Anand, 2020). Precision agriculture contributes the largest to the total value-at-stake at stake, which based on the study can be attributed to increased savings on input costs such as water, electricity, farm feed and fertilisers.

Table 23: Value at stake for the digitisation of agriculture for selected initiatives in 2026

	Value to society	Value to consumers	Value to agriculture industry	Total value at stake
Precision agriculture	R100 billion	R2 billion	R205 billion	R307 billion
Connected supply chain	R19 billion	R2 billion	R87 billion	R108 billion
Digital market place	R80 billion	R4 billion	R91 billion	R175 billion
Autonomous operations	R13 billion	-	R68 billion	R81 billion
Total value	**R212 billion**	**R8 billion**	**R451 billion**	**R671 billion**

Source: Accenture (2020)

The emerging and disruptive nature of smart farming present a huge opportunity for increased resource efficiency in the agriculture sector. The fourth industrial revolution is underpinned by smart farming technologies which enables farmers to monitor and manage conditions on farms. However, the viability of technologies such satellite imagery and drones is limited to medium and large sized farms operating at more than 40 ha. Thus, the used of sensors and mobile-based applications provide small sized farms with an alternative to monitor farm operations. Soil sensors are gaining traction in South Africa and there is medium-to-high growth potential depending on the target market. Similarly, the market for drone technology holds high growth potential in markets observing increased area under production. Coupled with these technologies, is the remote sensing services, which become attractive in markets with existing infrastructure as this allows for improved data management and decision making. Given this, a market opportunity map for smart farming technologies is shown in Figure 33. The map shows market growth potential for smart farming technologies that has been observed in soil sensors, drones and the associated services. Given the disruptive nature of smart farming technologies, remote sensing services show a higher market growth potential, especially for farms with existing infrastructure (hardware). Furthermore, the interest in a centralized database for better farm management and decision making, becomes attractive for remote sensing services. While soil sensors are gaining traction in irrigated agriculture. The limited financial viability of drone application to large-scale farm operations, limits the uptake of the technology to smaller operations, hence the medium market growth potential.

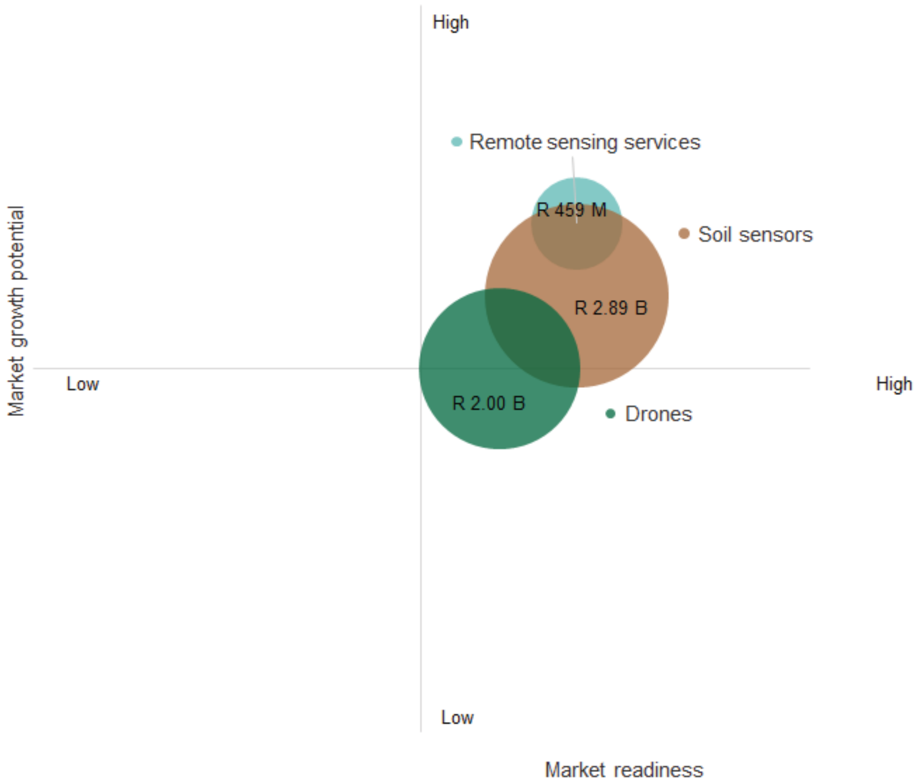

Figure 33: Market opportunity map for smart farming technologies

5.3. Undercover farming systems

Undercover farming (UF) or controlled environment agriculture (CEA) is a way of farming that allows for more favourable growth conditions, compared to open field farming. It aims to improve input efficiencies by using less water and space and results in quality of produce. Undercover farming involves different growing environments which can range from low-to-high tech systems, these include:

- Indoor farming which involves the production of crops using lighting such as LED lighting instead of sunlight and allows for the environmental conditions to be controlled. It can include production in rooms, warehouses, containers or factories.
- Vertical farming is production of crops in vertical layers. It is often suited for small spaces or high density spaces that require less land.
- Protected cropping, refers to crops grown outdoors under some form of protection such as tunnels, canopies or nettings. Greenhouses can be a glass or polycarbonate structure that uses sunlight in crop production. The grower maintains the proper light, carbon dioxide, temperature, humidity, water, pH levels, and nutrients to produce crops year-round. This form of growing environment allows for better climate control.

The different forms of undercover farming are shown in Figure 34 below (GreenCape, 2019).

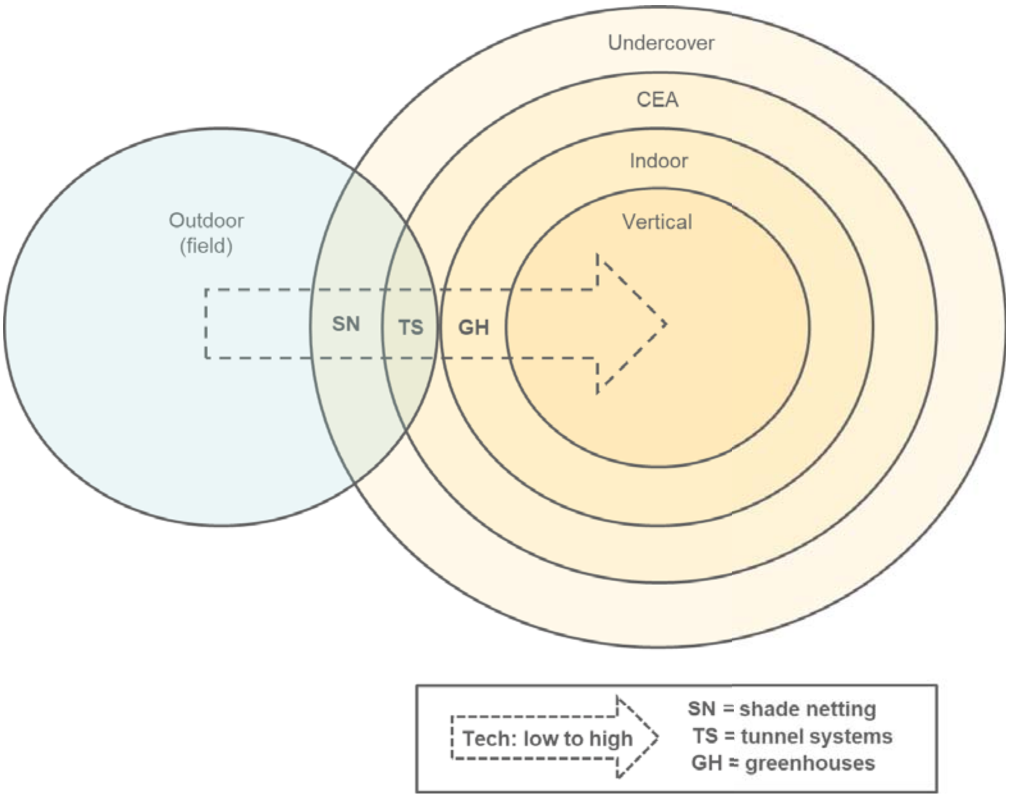

Figure 34: Undercover farming and its various forms (GreenCape, 2019)

In the different growing environments highlighted above, there are different growing methods that can be used. The methods described below do not use soil and reduces water loss, which makes them suited for growing indoors, vertically or in locations with poor soils and harsh climatic conditions.

- **Hydroponics** involve the growing of plants without soil while providing water, nutrients and oxygen. These types of systems include Nutrient Film Technique (NFT), Drip system, flow or deep water culture. Depending on the type of systems used these can be incorporated in greenhouses, indoor farming or vertical farming. Hydroponic growing systems use about 70% less than conventional production systems.
- **Aeroponics**: This is a form of soilless crop production using little water. The roots of the plants are suspended in the air and sprayed with nutrient and water solution. These are typically used in greenhouses and are considered the most water saving type of growing, using 90% less water than some hydroponic systems.
- **Aquaponics** involves the combination of aquaculture and hydroponics. A functioning systems results in the waste from the fish (ammonium and urea) and the bacteria in the system delivering all the required nutrients to the plants. Aquaponics relies on fast growing fish (tilapia, perch, catfish, trout, etc.) in order to supply the needs of the plants and can be set up indoors as they don't require soil.

5.3.1. Business case for undercover farming systems

The competitiveness of greenhouse production lies in the site selection. The main factors determining location and site selection of a greenhouse production area are: cost of production, quality of produced yield, and transportation cost to markets (FAO, 2013). Cost and quality of production depend on the local climate and the greenhouse growing conditions. Other technical aspects include water, electricity supply and labour. A study by Van der Merwe (2019) notes the advantage of hydroponic vegetable greenhouse production relative to open field production. There are economic, environmental and social advantages that can be attained from undercover farming systems, especially medium and high tech systems. These are provided below:

- Economic: Substantially higher yields / m^2 compared to conventional soil farming; hyperlocal produce which results in less transport costs; high quality and controlled environments which yields potential to export speciality produce; 'out of season' crop production resulting in better price for produce and cost competitive produce compared to conventional farming.
- Environmental: Growing food within and near cities reduces the transport distance from producer to consumer, which results in reduced carbon footprint; high quality produce results in less waste of fresh produce that is considered "ugly vegetables"; substantial water efficiency and reuse; lack of pesticide use and little fertiliser use and subsequent runoff results in eutrophication of water systems; reduced soil degradation in systems that use soilless mediums

- Social: Systems provide potential for increased job opportunities and multiplier in other sectors; and can supplement food supply during times of climate stress.

The financial returns of the different undercover farming systems are highlighted below in Table 24. The cost breakdown of a greenhouse hydroponic farm and small plot intensive farming (which is a form of farming that makes use of underutilised land in an urban area to plant and harvest fresh produce with intentions of generating profit) is shown for cultivation of lettuce and tomatoes, respectively. Due to the varied crops cultivated the gross margins from these systems cannot be compared. However, the capital, operating and potential margins of each system can be assessed. The greenhouse production system has high capital investment and operational costs but shows a positive gross margin under lettuce production. While small plot intensive farming has lower capital investment and operational costs compared to a greenhouse system but showed negative gross margins under tomato production. The noted benefits for greenhouse production systems and potential for positive gross profit margins strengthens the business case for greenhouse hydroponic production systems. Additionally, growing under protected shade netting can increase incomes per hectare between R95 000 and R100 000 per year, depending on the crop type.

Table 24: Expected returns from different systems with different crops

<table>
<tr><th colspan="2"></th><th colspan="4">Economic benefits</th></tr>
<tr><th colspan="2">Innovation type</th><th>Capital investment</th><th>Operational cost</th><th>Production costs</th><th>Gross margin (per annum)</th></tr>
<tr><td>Greenhouse</td><td rowspan="2">A case study of a 2750 m^2 greenhouse on 4000 m^2 planting lettuce and 4000 m^2 SPIN farm planting tomatoes per annum (based on (T.C. van Niekerk & Le Roux, 2019)</td><td>R 4 746 908</td><td>R2 463 515</td><td>R3 024 638
(R4,58 per plant)</td><td>R916 654</td></tr>
<tr><td>Small plot intensive farming (SPIN)</td><td>R278 735</td><td>R1 181 580</td><td>R1 190 000
(R14 per kg)</td><td>R-833 00</td></tr>
<tr><td colspan="2">Shade nets</td><td colspan="4">Depending on tonnage and crop type, the income per hectare can increase between R95 000 and R100 000 for crops under protected netting. Farmers in Elgin note that apple orchards covered with netting yielded 20-30% more apples compared to uncovered orchards due to protection against sun damage (DrapeNet SA, 2018).</td></tr>
</table>

5.3.2. Global market

Undercover farming in its various forms has grown significantly across the globe in the last few decades. The uptake of CEA in form of indoor and vertical farming is predicted to show the fastest growth. There is a growing number of companies all over the world involved in CEA. The application of CEA has predominately been observed in countries where:

- Food security is a key concern
- There is a strong political will and progressive policies

- There is a competitive innovation landscape (Blakthumb, 2020).

Examples of these include countries like Singapore, where there is a strong reliance on imports of fresh produce, which places the country at risk of food security. But the government of Singapore has a good reputation for investing in innovation and is investing in CEA start-up companies. In the Middle East, the United Arab Emirates invests heavily in CEA systems to ensure the country has access to food regardless of the desert conditions. Japan has intensive CEA plant factories which are among the largest in the world (UrbanAg, 2017). CEA companies in the United States are leading the innovation in CEA technology. Some of the well-known indoor farms in the U.S include Aerofarms, Bowery, Plenty, Gotham Greens and Square Roots. As a result of the strong investments and policies in these countries, the industry and sector is still growing.

In addition, the greenhouse systems are advancing globally to more automation and controlled environment agriculture. Some of the technologies integrated in greenhouses range from the type of covering material used to the control systems, which can include automatic greenhouse monitoring, response systems and the use of wireless sensors and Internet-of-Things based systems. Examples of these advanced greenhouse systems have been observed in countries like Canada, Australia and the US. The global market for undercover farming in different growing environments is outlined in Table 25.

Table 25: Global market size for undercover farming

Industry	Estimated global market value	Predicted growth by 2025
Indoor farming	USD 121.26 billion (2019)	USD 167.42 billion at a CAGR of 5.4%
Vertical farming	USD 3.13 billion (2019)	USD 9.96 billion at a CAGR of 21.3%
Greenhouses	USD 1.4 billion (2020)	USD 2.1 billion at a CAGR of 9.2%

Source: (Marketdataforecast, 2020)

5.3.3. South African market

5.3.3.1. Undercover farming market overview

Undercover farming in South Africa started in as early as the 1970s with producers growing vegetables under tunnels. Due to issues with soil borne diseases, the production systems evolved to the use of soilless mediums which are still used today. The uptake has increased since the 1990s with more farmers adopting undercover farming systems. Undercover farming in South Africa encompasses greenhouses (plastic tunnels and multi-spans) and shade netting. These can be found in major agriculture areas in Limpopo, Mpumalanga, KwaZulu-Natal, Gauteng, and the Eastern Cape and Western Cape provinces. The uptake of these systems in South Africa is broadly described below and detailed by farm type and commodity sub-sector in section 5.3.3.2 and 5.3.3.3.

- **Shade netting and tunnels (low-medium tech).** Farms with shade net structures are found in provinces where table grapes, nuts, citrus, deciduous fruit, avocadoes, apples and berries are grown, which is predominately in the Western Cape (Lindi Botha, 2020). Netting prevents pests and disease damage, reduces water usage and protection against extreme temperatures and climate stress. The area under shade netting and tunnels in the Western Cape is shown Table 26

Table 26: Undercover farming systems in the Western Cape

Undercover farming component	Indicator	Value
Shade netting	Total area of production: 2013	918 ha
	2017	2 494 ha
	Increase in production area	1 575 ha
	Increase (%)	172%
Tunnel systems	Total structures: 2013	4 704 structures
	2017	7 290 structures
	Increase in structures	2 586 structures
	Increase (%)	55%

Source: based on (WCDoA, 2018)

- **Greenhouses (high-tech).** Vertical farms in the form of hydroponic rooftop gardens and controlled environment agriculture is emerging in South Africa. Farmers across Gauteng are adopting rooftop gardens, where A-frame racks are used to grow produce hydroponically. About seven farms were implemented in 2017 (see box 3) and a further 60 farms were planned for the next three years (dating to 2020). Furthermore, commercial and semi-commercial vertical farms have been set-up in Pretoria using a range of growing methods in greenhouses. A key example is the CAN-Agri vertical farm, which is a full-scale commercial farm of about 5000 m^2 based in Pretoria. The farm is comprised of 4 greenhouses of about 800 m^2 each, a nursery and a training centre. The greenhouses utilise smart irrigation systems and automated processes to optimise production. The farm has been operational for less than a year and produces a range of leafy greens and herbs to local markets (CAN-Agri, 2020).

Box 3 : Undercover farming as a social and institutional innovation

With the rapidly urbanising countries, undercover farming systems can provide rural-urban linkages and contribute to local economic growth. This has been observed in urban agriculture initiatives in South Africa utilising undercover farming systems to address youth unemployment and food insecurity.

The Urban Agriculture Initiative (UAI) is a key example of a social and institutional innovation that brings together key actors along the food value chain. The initiative established a programme in 2017 that supports entrepreneurs in the urban agriculture sector, through hydroponic rooftop farming. The programme was a combined effort of key value chain actors, which included:

- Johannesburg Inner City Partnership (JICP) developed and co-ordinates the project that supports young urban farmer entrepreneurs from Johannesburg's inner city.
- Wouldn't It Be Cool (WIBC) is an entrepreneur incubator that manages the process of identifying and training the potential farmers from the inner city. During the 18-month training, farmers are expected to pitch their business models and demonstrate that their business can be sustainable and can generate at least R600 000 per year. Once the farmer is allocated a site, WIBC incubates their business for 12 months, to ensure business continuity once the entrepreneur exits the programme. As of the end of 2019, 22 farmers and 15 agro-processors have completed training under the project.
- Small Enterprise Development Agency (SEDA) funds the entrepreneurial training (valued at ~R500,000 per beneficiary). The farmers are also offered a zero-interest loan to cover the primary production start-up costs (~R300,000 per site). Most of the farms include a greenhouse ranging from (21 m x 7 m) to (28 m x 8 m) in area, with agri plastic and shade netting, and also include hydroponic infrastructure. These start-up costs are offered as a loan, rather than a grant, as this places pressure on the entrepreneur to develop a sustainable business model.
- City of Johannesburg (CoJ) has recently joined the project and has offered 27 of their buildings for rooftop farms.
- Inner city property owners enter into lease agreements directly with the farmers, who are responsible for paying the leases. However, WIBC pre-negotiates lease terms on behalf of their entrepreneurs, and acts as a guarantor, should the farmer's business fail (in this instance WIBC may replace the failed entrepreneur with another entrepreneur). This benefits both the farmers (who often do not have the negotiation skills) and the property owners (who may view the entrepreneurs as risky tenants). WIBC also helps the farmers identify sites. During the entrepreneurial training, WIBC undertakes site surveys to identify suitable buildings and, by the time the entrepreneurs pitch for the start-up funding, WIBC begins to pair them up with a site.

The Urban Agriculture Initiative is also looking to run similar initiatives in other parts of South Africa, and has already secured projects in the East Rand and Mpumalanga. In the East Rand, the initiative is working with Umsizi Sustainable Solutions through the broad based livelihoods project, the University of Johannesburg's business school, iZindaba Zokudla and chef organisations (such as Chefs with compassion and Slow food) to set up tunnel farm units and using deep-trenched water beds in community food gardens. The project links households and communities to food and local markets, while addressing food security and promoting local economic growth.

According to UAI, previous urban agriculture projects that have been run by government have been less flexible (including procurement) with limited scope to partner with other organisations, and have failed as a result. UAI believes that one of the reasons the programmes have been successful is because of the linkages to the different actors along the food value chain and building a 'network of networks'.

Source: Urban Agriculture Initiative

According to StatsSA (2020), 29 352 ha of arable land in SA is under protective cover. While it is unclear what composition of this area is for the different undercover farming systems, some statistics were provided on undercover farming area under greenhouses, tunnels and shade nets from undercover farming technology suppliers, these are shown in Table 27. Low-to-medium tech systems such as tunnels and shade nets make up about 80% of the total area, while greenhouses make up 20% of the total area.

Table 27: Undercover farming statistics

Undercover farming statistics in South Africa[34]	**Area (ha)**	**Percentage**
Greenhouses	3000	19.62%
Shade netting	5000	32.70%
Tunnel systems	7290	47.68%
Total	**15 200**	

5.3.3.2. Market trends by farm type

The market uptake of undercover farming systems by the different types of farms in South Africa depends on the production or growing methods. As shown in Figure 35, most farm types in an African context shift from low-tech systems that produce for the domestic market towards high-tech systems for farms producing for the export market. There are further small-scale farming operations that takes place in and around urban areas, which, in most cases has been for subsistence but is currently emerging to supply niche produce to the local markets. The technology development pathway highlighted below (Figure 35) is not always the case for most farm types and depends on the varied definitions of farm-types.

[34] These statistics were estimated by tech-suppliers, hence, why they do not correspond with the estimated area from StatsSA.

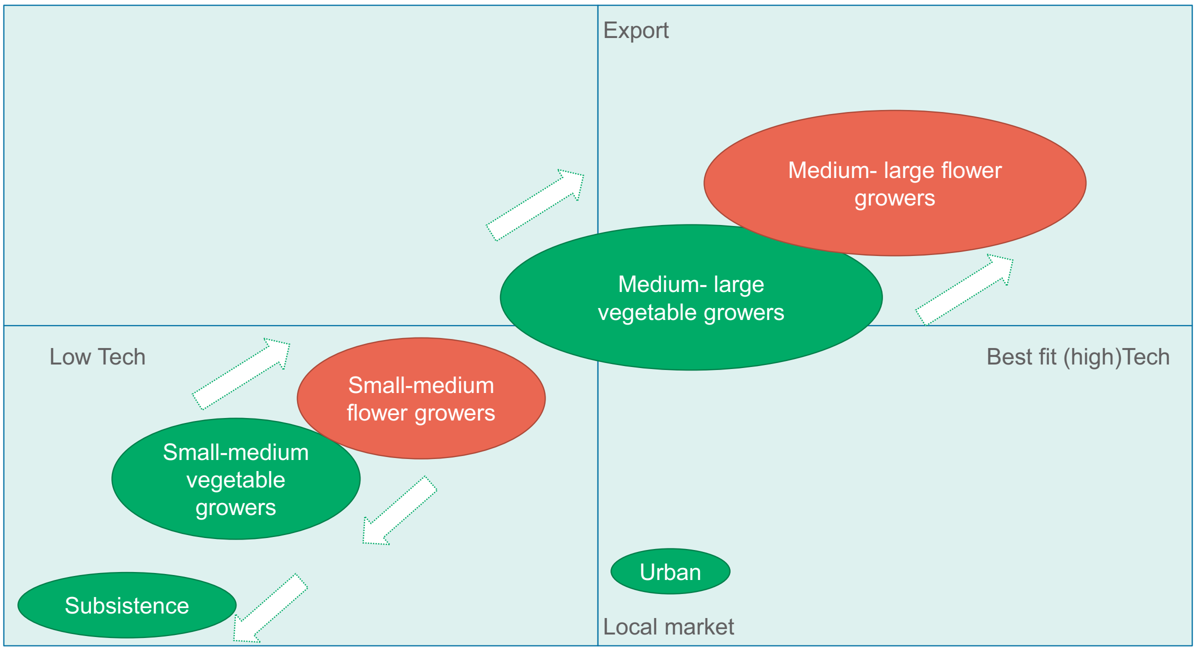

Figure 35: Technology development trends for undercover horticulture production by farm type in Africa based on (De Visser & Dijkxhoorn, 2012)

The type of undercover production systems applied by South African farmers follow a similar trend shown in Figure 35. The production system by farm type (subsistence, smallholder, emerging and commercial) are detailed in Table 28. The uptake of low-tech systems such as shade nets has been observed among subsistence, smallholder and emerging farmers, while medium systems such as hydroponics in medium tech greenhouses is predominately among emerging and commercial farmers and high tech systems are largely among commercial farmers. Depending on the opportunities available, farmers may transition to a different type of technology to improve farm productivity.

Table 28: Classification of South African undercover horticulture

	Technology Type		
	Low	Medium	High
Cover type	Shade net	Plastic roof, net walls	Plastic, glass
Average size	0-5 ha	5-100 ha	100-1500 ha[35]
Production process	Soil	Hydroponics	Hydroponics, Climate control
Cooling systems	Natural ventilation	Natural ventilation	Pad & fan
Farm type	Subsistence – emerging	Emerging – commercial	Commercial farmer

Source: Based on De Visser P., Dijkhoorn (2012)

5.3.3.3. Market trends by commodity sub-sector

The market uptake of undercover farming systems in South Africa has largely been in the floriculture and horticulture sector. The main crops that are grown in

[35] Flower farmers tend to range from 0.5-40 ha

greenhouses are tomatoes, cucumbers, sweet peppers, lettuce, aubergine, herbs, strawberries, melons, gem squash, baby marrows and green beans (Venter, 2013). The area of orchards and vegetables under shade nets and tunnels in the Western Cape is shown in Figure 36. The orchard area under shade netting increased by 1625 ha (291%) from 2013 to 2017. According to the flyover data from BFAP and WCDoA (2018), the largest contributors to the increase were grapes, naartjies, and blueberries. The vegetable area under shade netting increased by 6 ha (2%) between 2013 and 2017, while the area under tunnels increased by 56 ha (46%). The major vegetable crops that contributed to the increase were broccoli, cauliflower, lettuce and peppers for shade netting and lettuce, cucumbers, celery and peppers for the tunnel area (Pienaar, 2018).

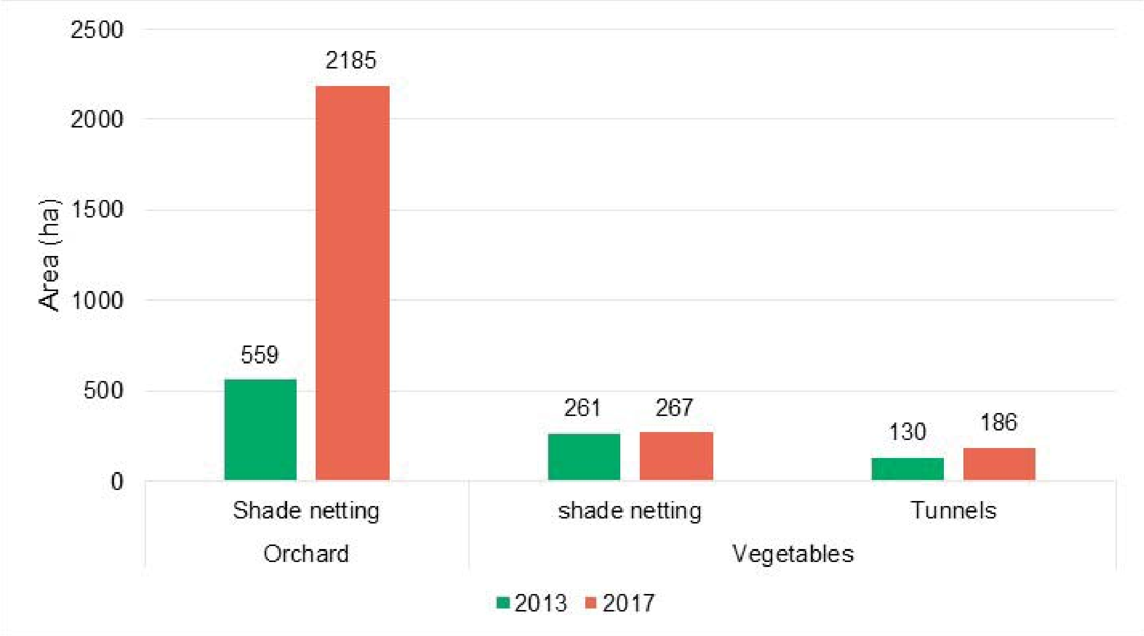

Figure 36: Area of orchards and vegetables under shade nets and tunnels in the Western Cape (Pienaar, 2018).

Most vegetables produced in South Africa are for the domestic market and only a small amount is destined for exports. The fresh produce market is the main channel for sale of vegetables in South Africa. About 46% of vegetable production is sold through the local fresh produce markets, 42% is sold through direct sales and own consumption, 10% are processed, and only 2% are exported (Dube et al., 2018). The large domestic market and distribution channels are indicative of the demand for food products and supply of quality fresh produce. These are further illustrated in Figure 37.

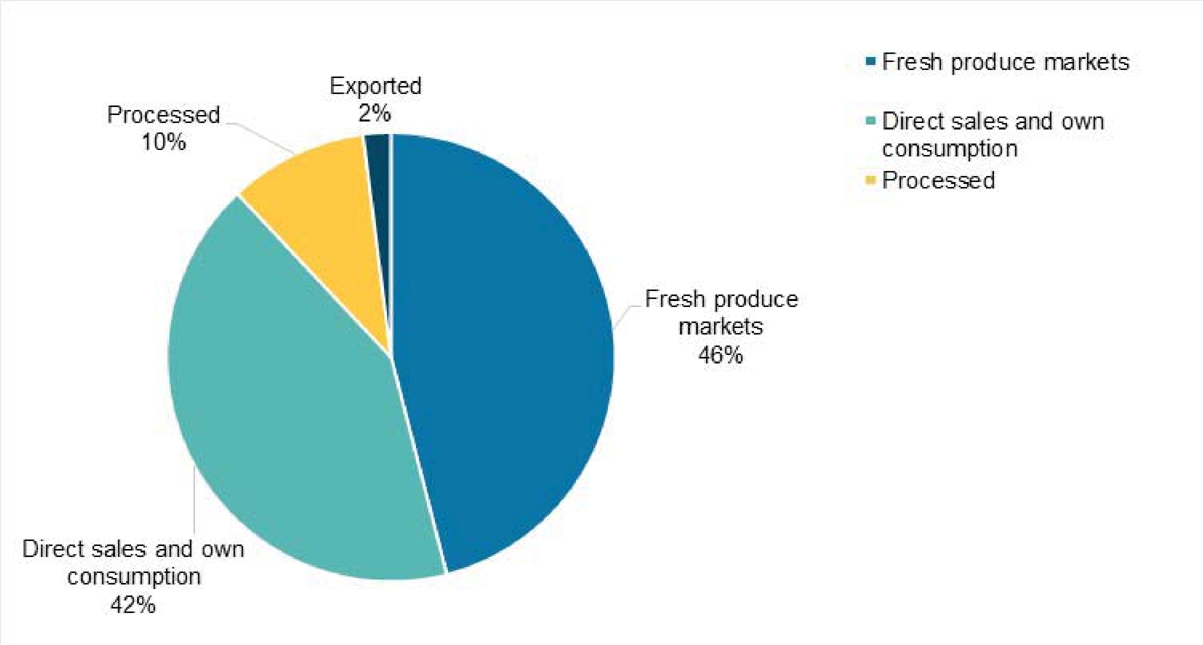

Figure 37: Distribution channels for vegetables in South Africa

There is an increasing demand for local food and constant supply of quality fresh produce. The growth in demand for fresh produce is anticipated to drive the uptake of hydroponic greenhouse or indoor farming, as it provides an opportunity for intensive production of fresh produce.

Figure 38 shows the area harvested for selected crops that are grown in undercover farming systems. While this data does not reflect the area for undercover systems, the market demand for the selected crops can be derived. Berries showed the highest average annual growth rate between 2008 and 2018 growing at 9.63%, followed by cucumbers at a rate of 2.22% and green beans at 1.92%. Although tomatoes have the highest area harvested, the area harvested declined at a rate of 0.91% in the same period. The decline in area can be attributed to unfavourable climatic condition or high production costs (DALRRD, 2019).

According to a report by Mordor Intelligence, the fruits and vegetables market in South Africa is projected to grow at CAGR of 6.5% during the forecast period of 2020-2025 (Mordor Intelligence, 2019). The projected growth in fruits and vegetables holds potential for undercover farming systems to meet the growing demand.

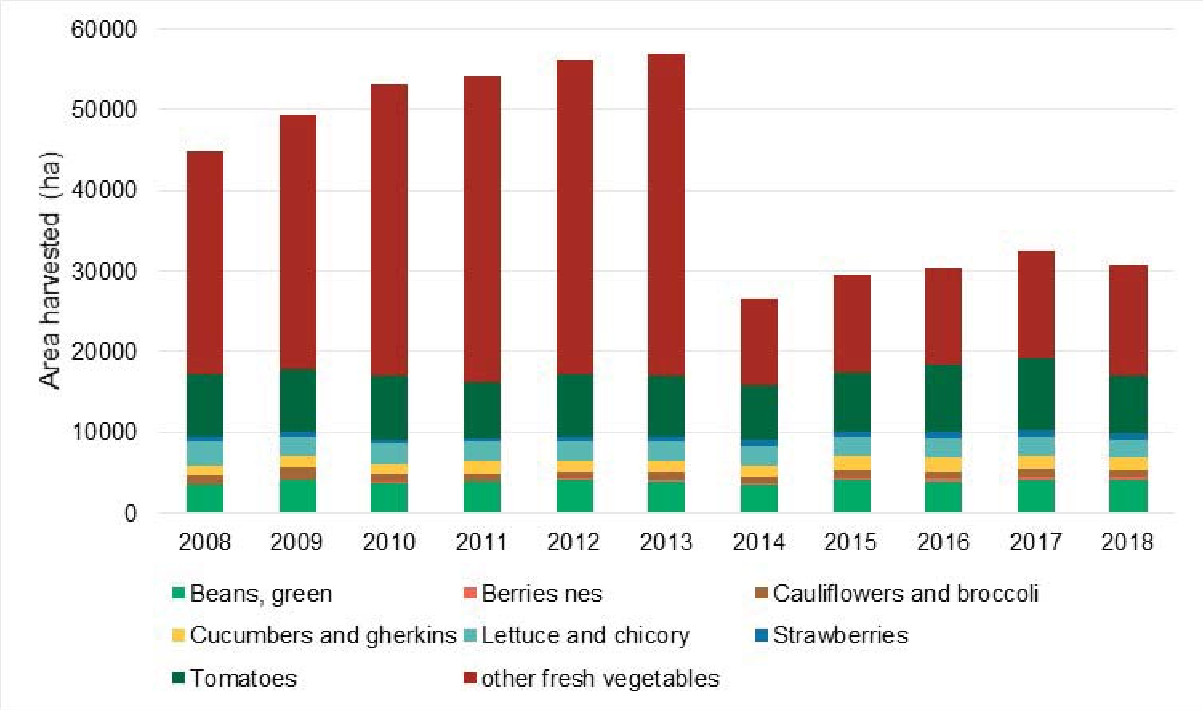

Figure 38: Area harvested under selected crops grown in undercover farming systems (2008-2018) (FAOSTAT, 2018)

5.3.4. Market barriers

Technology	Commercial farmers	Smallholder farmers
Undercover farming systems	• **High initial investment cost** especially for high-tech systems which have specialised lighting and equipment. • **Electricity costs.** Indoor farming systems have a high energy requirement, which result in high electricity costs. This is a limiting factor to businesses that want to enter this market. • **Access to land or suitable space**. A key challenge noted in scaling indoor farming is the competition for land use within city bounds.	• **Access to markets**. In cases where tunnel farms have been implemented at household level or at a small-scale, a key barrier noted was accessing markets. • **Limited of technical skills and knowledge**

5.3.5. Market opportunity

This section highlights the market size estimate, market driver and the different factors that are likely to contribute to growth of undercover farming technologies.

5.3.5.1. Market size estimate

According to StatsSA (2020), the total arable land in South Africa in 2018 was estimated at ~7.6 million ha. The area under protective cover made up ~0.39% of the total arable land (29 352 ha). While, land use for crop production makes up 78.56% (5.9 million ha) of total arable land use, cultivated pastures ~17.14% (1.3 million ha) and fallow land ~3.90% (297 111 ha). This is further illustrated in Figure 39.

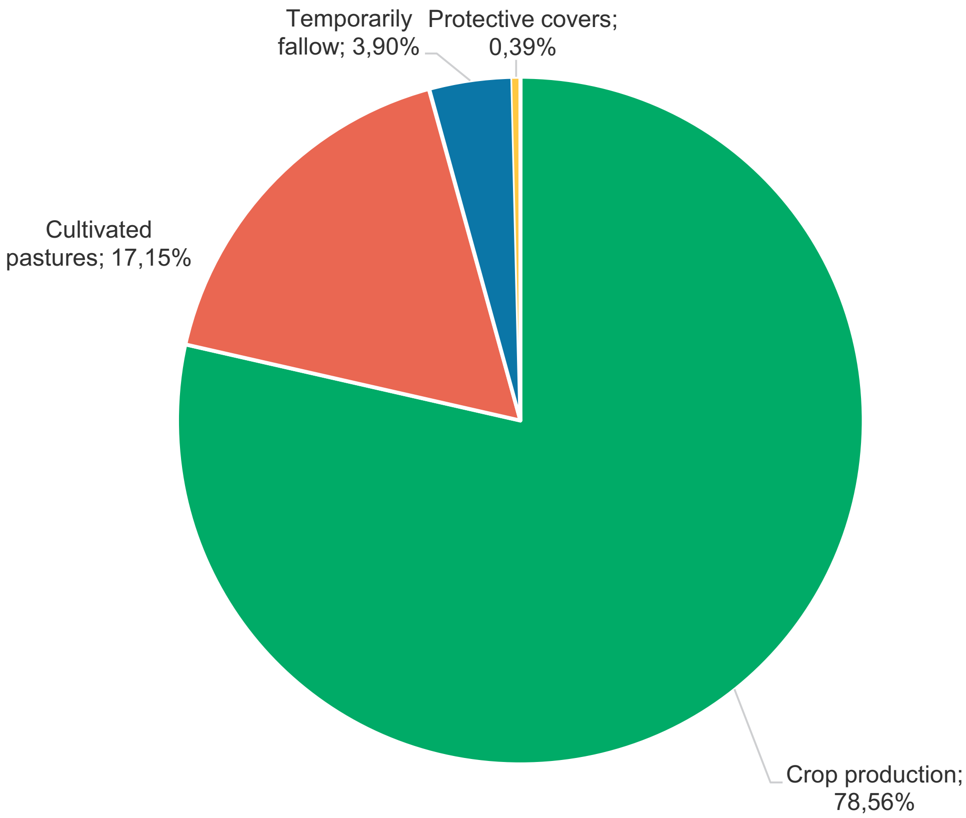

Figure 39: Arable land use in 2018 – StatsSA, 2020

Based on costs determined from surveys and interviews, low-to-medium tech systems and high tech systems have a minimum cost R100 000/ha and R2 million/ha respectively. Assuming that ~0.5% of the current area under crop production is protected, then the market size for low and medium tech system is conservatively estimated at R2.40 billion and R11.74 billion for high tech systems. The formula used is provided below and the market size estimate is detailed in Table 29.

Market size estimate = potential area x cost of technology

Table 29: Market size estimate and readiness level for undercover farming systems

Innovation	Market readiness	Potential Area (ha)	Market size[36]
High-tech systems (Greenhouses)	H	5868,23	R11.74 billion
Low-tech systems (shade netting & tunnels)	M-H	24040,20	R2.40 billion

5.3.5.2. Market drivers

The market growth for undercover farming systems can further be attributed to the following drivers:

- **Urbanisation:** South Africa's urban population is growing rapidly, 63% of the population lives in urban areas and it is anticipated that it will rise to 71% by 2030 (PMG, 2018). The growing population drives a demand for food in both quantity and quality. Given the scarcity of natural resources highlighted above, there is a need for innovative ways to grow food to meet the increasing demand.
- **Climate change and water scarcity.** The climate uncertainties and limited water resources are a key driver for undercover farming systems, as these allow for improved growing conditions.
- **Consumer preferences:** The localisation of food involves growing more food to meet the growing demand and also transforming the food system through shorter distances and ways food is stored and consumed. The COVID-19 pandemic highlighted a greater need for more local food production and undercover farming systems provide alternative production systems that can complement food production in the country.

5.3.5.3. Market growth potential

The market potential for undercover farming technologies lies in the transition of current farmers to either low, medium or high tech systems and in the market demand for fresh produce. The number of farmers in South Africa involved in horticulture production is shown in Figure 40. There are 15 054 market-oriented smallholder farmers and 3 994 micro, small, medium and large scale commercial farmers involved in horticultural production. It is unclear how many horticultural farmers have adopted undercover farming systems. However, based on the data shown in Table 28, it can be assumed that most smallholder and micro and small commercial farmers have adopted low-to-medium technology systems and medium-large scale commercial farms have adopted high-tech systems. Considering that most of the smallholder farms and micro farms are growing in soil, there is opportunity for these farms to transition to medium or high-tech growing systems, provided there is an enabling environment in place for farmers to adopt the technologies. There is further potential for some of the farmers (~10 000) that currently have no systems to also transition to low, medium or high-tech systems.

[36] The market size was based a ~1% conversion of the current area covered for crop production into protective systems. The representation of protective systems (i.e. greenhouses, tunnels and shadenets) were based on current representation shown in Table 27.

Visser (2012) noted that emerging and commercial farmers can transition from low tech to high tech systems depending on the opportunities presented.

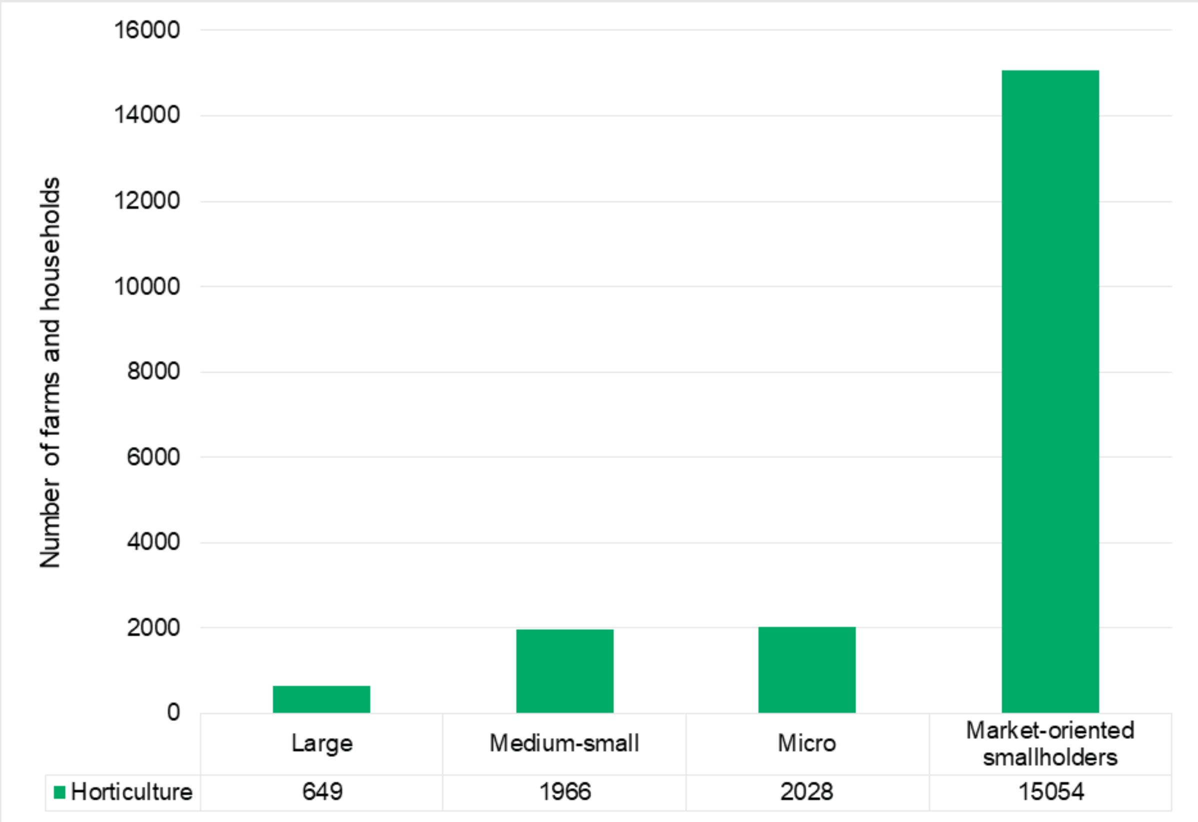

Figure 40: Number of farms and households in horticulture in 2017 (BFAP, 2020)

Further opportunities that could contribute to the growth of undercover farming systems are described below.

- **Export market demand**: Although South Africa is a net exporter of agricultural products, there are growing export markets that the country could take advantage of in the fruit and vegetable industry. High growth markets in South and East Asia such as China, Vietnam and India are key markets presenting opportunities for fruit exports. According to (Chisoro & Mondliwa, 2019), imports of fruit and nuts in China grew at a CAGR rate of 38% in the last five years. Additionally, the vegetable market is often depressed due to oversupply, and thus in order for the local industry to grow, the export market will need to expand (Van Lin et al., 2018). The export market for vegetables is currently in the Southern African Development Community (SADC) countries. There is growing interest in Asia from countries such as Hong Kong, Singapore and Malaysia. A study by Martin Cameron (2014) noted that there were an estimated 687 realistic export market opportunities for fresh vegetables from South Africa, which represented a potential of about R32.6 billion (Steenkamp, 2018). Given this, there is potential for high-value export industries to leverage off the benefits of high-tech systems in providing high quality year-round produce with minimal environmental impacts to tap into the greater export markets.

- **Specialised crops** for pharmaceutical and beauty treatments such as cannabis are anticipated to create an opportunity for uptake of undercover farming systems. The production and use of cannabis in South Africa has been gradually legalised. The country is a large producer of cannabis on the continent with an estimated production of 2500 tonnes per year. The Eastern Cape and KwaZulu-Natal provinces offer a suitable climate for cannabis cultivation. The industry is growing rapidly and presents opportunities for greenhouses and indoor farming technologies. The estimated market for cannabis and related products will be worth R27 billion by 2023. The export market for cannabis is unknown, but according to the African Cannabis report, how much of the export market South Africa can secure will depend on the water and irrigation infrastructure available (Keenan et al., 2019).

It is evident that there is a growing demand for produce that is currently grown in undercover farming systems. Given the emerging nature of high-tech farming systems, the market opportunity for undercover farming systems will be much higher for these systems compared to medium-to-low tech systems. However, there is potential for medium-tech systems for farmers currently operating low tech systems or no tech. The market opportunity map for undercover farming systems in displayed in Figure 41.

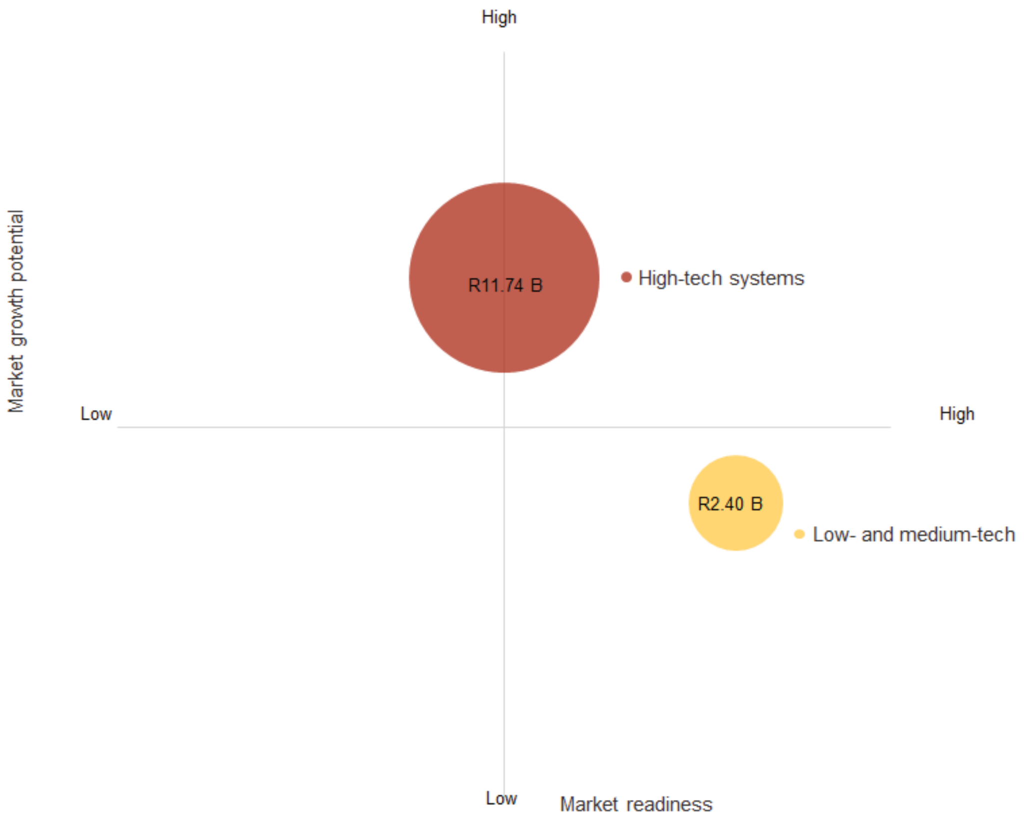

Figure 41: Market opportunity map for undercover farming systems

5.4. Sustainable practices

Detrimental environmental effects associated with conventional agricultural practices (e.g. the use of synthetic chemical fertilizers, pesticides and herbicides, intensive tillage and monoculture), lowers the return on soil, and due to loss of arable land this drives farmers to convert to more sustainable practices. These practices include conservation and regenerative agriculture. Conservation agriculture (CA) has three principles, with the main purpose of improving soil health. These are:

- Minimum soil disturbance
- Permanent soil cover
- Crop rotation

Regenerative agriculture (RA) is essentially CA evolving with new management principles as many farmers move away from conventional farming practices, which are considered unsustainable. The principles of RA are based on the same concept, but takes a more holistic approach due to the addition of cover crops and, in some systems, grazing. These principles broadly aim to add biodiversity (above and below ground) and improved soil health to the system so as to increase production resilience. Cover crops are an important component of regenerative agriculture and improves soil health and productivity through:

- **Physical stability**: It limits loss of soil and nutrients and it retains the soil floor
- **Nutrient cycling and retention**: It improves nutrient recycling (which reduces the need for input nutrients like nitrogen) and limits water loss.
- **Improved hydrology**: It improves water infiltration and water holding capacity, cools soil temperature and decreases evaporation.
- **Increases biodiversity** (above and below the soil): This improves biological control and balances soil biology.

5.4.1. Business case for conservation and regenerative agriculture

The benefits of adopting conservation and regenerative agriculture practices are well-researched (Du Toit, 2017; GreenFund, 2016). The major economic and environmental benefits include reduced input costs, higher yields due to improved soil health, greater resource efficiency with less water and fertiliser requirement. The economic viability of conservation agriculture practices is further noted below.

A study conducted by the KwaZulu-Natal Department of Agriculture noted that no-till systems require less capital, labour and fuel compared to other tillage systems. Additionally, the time spent in land preparation and planting of no-till crops is less than other tillage systems. The agrochemicals and nitrogen costs are higher for no-till systems compared to conventional tillage systems. However, the higher levels of soil moisture conserved with no-till can result in yield benefits of about 2t/ha in dry seasons. In addition to the highlighted benefits, no-till systems allow for greater resource efficiency, i.e. less water and fertiliser are required.

In addition to no-till systems requiring less capital and input costs compared to conventional tillage, the systems have a shorter pay-back period and a positive net-present value (NPV) compared to conventional tillage. Most studies (GreenFund, 2016; Tafa, 2017) note a positive NPV after 10 years. This can be seen in Table 30 which compares the NPV and Internal Rate of Return (IRR) for conventional and no-tillage systems for different crops in the Eastern Free State (WWF, 2018b). The NPV after 10 years was positive for no-till systems and the payback period was half that of conventional systems. There are thus great economic and environmental incentives to the adoption of CA systems.

Table 30: Comparison of Net Present Value and Internal Rate of Return for conventional and reduced tillage in Eastern Free State

	CONVENTIONAL TILLAGE			NO-TILLAGE		
	SCENARIO 1	SCENARIO 2	SCENARIO 3	SCENARIO 4	SCENARIO 5	SCENARIO 6
CROP	Maize	Soybeans	Soybeans-Maize Rotation	Maize	Soybeans	Soybeans-Maize Rotation
NPV at 10 years	-924 677	- 1 653 095	-1 294 913	1 873 220	1 068 627	1 464 266
Payback period in years	12	15	13	6	7	6
Real IRR at 10 years	1.3%	-3.8%	-1.2%	28.5%	19.2%	23.4%
Real IRR at 20 years	13.8%	10.5%	12.1%	33.7%	26.5%	29.6%

Source: (WWF, 2018b)

5.4.2. Global market

Conservation and regenerative agriculture has received increasing interest as a means to drive climate mitigation in the agriculture sector and to reduce soil degradation. The global uptake of conservation agriculture is growing rapidly. The estimated global area covered under no-tillage grew from 106 million ha in 2008/09 to 180 million ha in 2015/16. The growth of CA has been linked to the demonstrated benefits such as greater farm productivity and output, reduced costs of production, increased farm profitability and improved soil health. The greatest adoption of CA practices has mainly been in North and South America, Australia and New Zealand. The area under cropland production by region in 2015/16 is further shown in Table 31. As indicated, the adoption of no-till systems in Africa is low compared to the rest of the world (Kassam et al., 2019). However, the area under no-till in Africa has increased significantly by 211% from 0.48 million ha in 2008/09, thus showing an increasing adoption of no-till systems.

Table 31: Cropland area under no-till (M ha) by region in 2015/16

Region	CA cropland area (million ha)	Percent of global CA cropland area
South America	69,9	38,7%
North America	63,18	35,0%
Australia & New Zealand	22,67	12,6%
Asia	13,93	7,7%
Russia & Ukraine	5,7	3,2%
Europe	3,56	2,0%
Africa	1,51	0,8%
Total	180,44	

Source: (Kassam et al., 2019)

The interest in regenerative agriculture has grown beyond the farm-level and is emerging among impact investors. This has been in the form of various financing models such as crowdfunding platforms, loans and carbon marketplace that incentivises or enhance improved soil health. Examples of how these models are emerging globally are provided below (Farrell, 2020):

- Crowdfunding platforms that connect farmers: Platforms such as Kickstarter, Indiegogo and Barnraiser allow entrepreneurs and farmers to campaign and fundraise for their regenerative farming initiatives.
- Loans: Companies like Grow Ahead are using crowdfunding platforms to raise money to provide loans to smaller farmers. Investors earn a financial return from farmers lease repayments.
- Carbon marketplace: Nori, a Seattle-based company operates a blockchain marketplace to provide carbon accounting. The company recently partnered with LocusAg to provide ways for farmers to get paid for improved soil health. Similarly, Indigo Agriculture launched a marketplace that facilitates an incentive payment per ton of captured carbon from food companies wanting to sell carbon-negative products.

5.4.2.1. Market for conservation and regenerative agriculture technologies

- **No-till machinery**. The key technology component for CA and RA is no-till planters and it is mostly applicable for field crop production. It enables farmers to practice minimum soil disturbance, which improves soil health and consequently increases soil water infiltration and water holding capacity, i.e. increases water use efficiency. The global market size for planting and fertilising machinery is estimated at USD11 billion in 2020 and is projected to reach USD 15.70 billion by 2027, growing at a CAGR of 5.2% over the period 2020-2027. The dominant markets for cultivating machinery are located in the USA, followed by China. Japan and Canada are also growing markets for farm machinery (Researchandmarkets, 2020).
- **Biofertilisers**. Biofertilisers or often termed ‘biostimulants’ are products containing natural micro-organisms that are multiplied to improve soil fertility and crop productivity (Mazid & Khan, 2014). The use of biofertilisers improves the build-up of plant nutrients by applying the nutrients directly to the root or plant surface to stimulate growth. The increased microbial biota improves soil water uptake and act as biological controls. Biofertilisers are also beneficial in drought prone areas where the products enable crops to survive in stressful environments through improved water use efficiency. The typical biofertilisers are plant growth promoting rhizobacteria[37] (nitrogen-fixing) such as azospolillum or pseudomona. The global market for biofertilisers was valued at USD 1.03 billion in 2019 and is estimated to grow at an annual rate of 12.8% from 2020 to 2027 (Grandview research, 2020a). Biofertilisers exist all over the world, but the nitrogen-fixing biofertilisers control the largest part in the global

[37] Rhizobacteria are root bacteria that from symbiotic relationships with many plants

biofertiliser market. North America held the largest share of the global biofertiliser market in 2017, valued at USD 0.495 billion, followed by Europe at USD0.45 billion, then Asia-Pacific at USD0.284 billion, South America at USD0.24 billion and lastly Africa at USD 0.044 billion (see Figure 42).The biofertiliser market in Africa is still small, with some of the main biofertiliser producing countries being South Africa, Egypt and East African countries (Soumare et al., 2020).

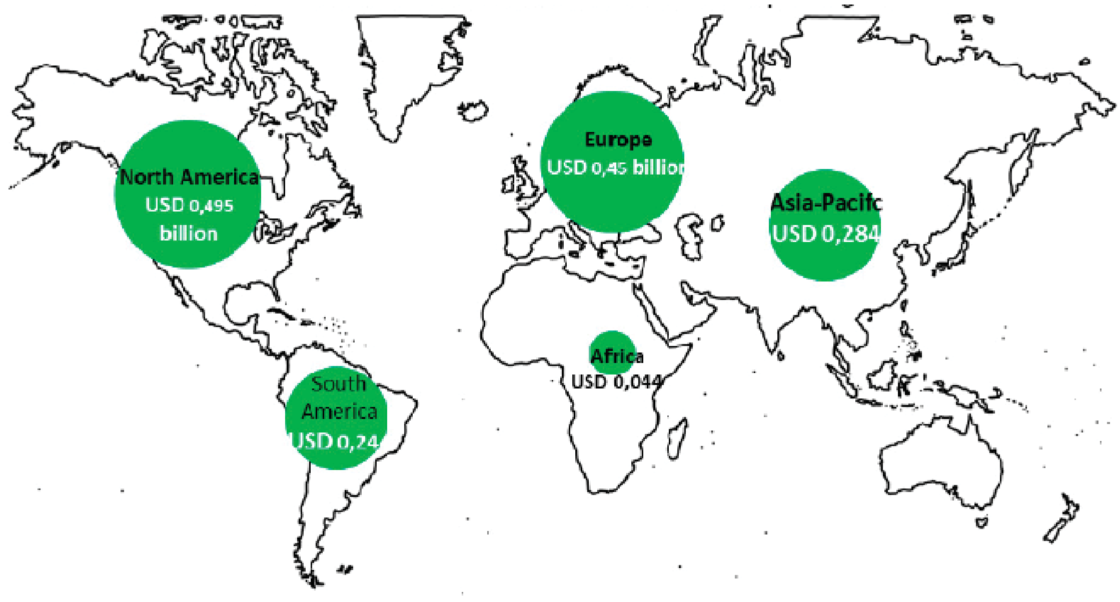

Figure 42: Global biofertiliser market and distribution (Soumare et al., 2020)

5.4.3. South African market

5.4.3.1. Market overview

The application of conservation agriculture practices has grown in South Africa. The area under no tillage in South Africa has increased by 19% from 2008/09 (368 000 ha) to 2015/16 (439 000 ha)(DALRRD, 2017; Kassam et al., 2019). The highest adoption rate of conservation agriculture in South Africa has been observed among winter cereal producers and is estimated to be between 20% and 30%, with the highest proportion of farmers (>70%) registered in the Western Cape. The adoption rate in KwaZulu-Natal is estimated at between 50% and 60%, while it ranges between 10% and 40% in the Free State, Mpumalanga, Gauteng and North West Provinces. The lowest proportion adopting grain producers is estimated in the Eastern Cape (5%), followed by the Northern Cape (6.5%) (Blignaut et al., 2015).

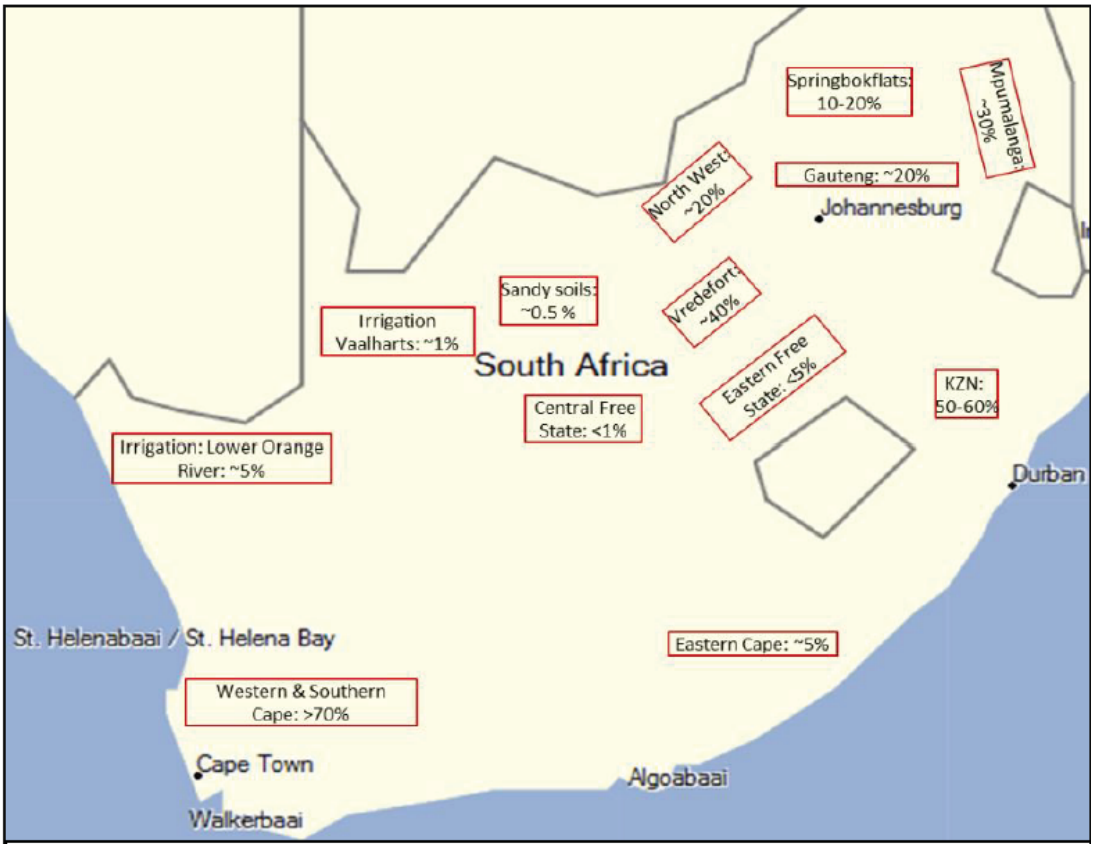

Figure 43: Distribution of conservation adoption among grain producers in 2014 (based on Sybrand Engelbrecht, Maize Trust, 2015)

The adoption of the CA in the different provinces has largely been enabled by support services and initiatives that promote conservation and regenerative agriculture. These are noted in Table 32.

Table 32: Initiatives supporting uptake of regenerative agriculture

Industry associations & farmer initiatives	**CA support services**
Grain South Africa	The grain commodity organisation, provides support on CA to its members, and hosts CA promotion days for small-scale farmers.
The No-Tillage Club in KwaZulu-Natal	An active association of farmers. It produces newsletters, hosts an annual conference, and conducts educational and outreach activities
Conservation Agriculture Western Cape	CA Western Cape is a forum of 185 paying members including producers, researchers and related sectors, aimed at knowledge sharing to advance CA.
Regenerative Agriculture Association of South Africa	RegenSA works on educating farmers and consumers about the true cost of Industrial Agriculture – the depletion of soils, the destruction of the carbon cycles and redirect SA agriculture to regenerative methods.

The uptake of key technologies used in conservation agriculture are highlighted below.

- No-till machinery is the main technology used in conservation agriculture. Most of the CA machinery that is used in South Africa is imported, approximately 80% of agricultural machinery is imported from countries like Brazil and China.
- In addition to no-till machinery, bio-based fertilisers are increasingly being used to improve soil health. The use of fertilisers in South Africa is shown in Figure 44. The data in the graph shows that nitrogen fertilisers are the most widely used and the demand for fertilisers has been relatively stable in the period of 2006 to 2016. Although there are industry players that dominate the fertiliser market, South Africa has become a net importer of fertilisers. According to Rose et al. (2014), biofertilisers could replace 52% of N-fertiliser and result in increased yields. The use of biofertilisers in South Africa dates back to the 1950s. The rapid expansion of commercial biofertilisers necessitated the establishment of an independent control body. South Africa is the largest consumer of plant biostimulants in Africa, consuming 49% of the total African biostimulants (Mordor Intelligence, 2016). The potential of biofertilisers is increasingly being exploited in agricultural practices through the cultivation of legumes. Numerous strains of beneficial microbes have great potential in the development of biofertiliser products. There are several studies being conducted in South Africa that are exploring the competitiveness of commercial and indigenous rhizobial strains.

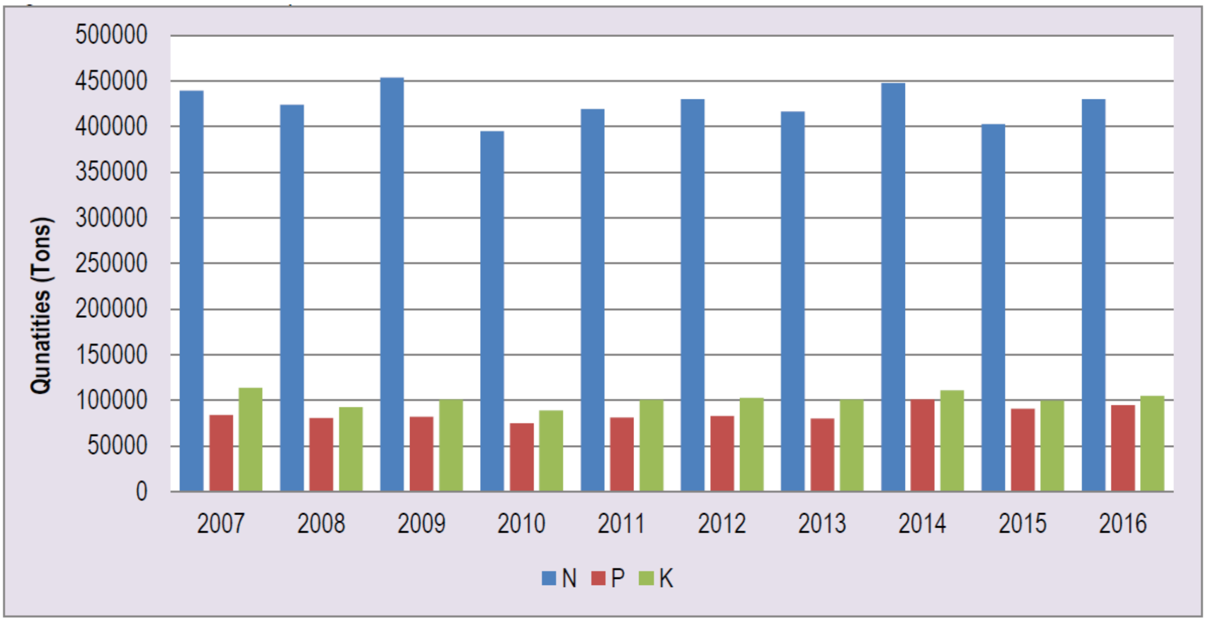

Figure 44: Fertiliser consumption in South Africa, 2006-2016 (Fertasa, 2016)

5.4.3.2. Market trends by farm type

In South Africa, approximately 15 to 20% of commercial farmers and only 5% of smallholder grain farmers have adopted conservation agriculture (WWF, 2018). The degree of adoption differs from province to province. Based on a study conducted by the Agricultural Research Council and WCDoA (2015), approximately 49% of the farmers' surveyed in the Western Cape use all three conservation agriculture principles, while the remainder adopt one or two of the CA principles.

The adoption of CA practices by smallholder farmers have been well-documented in the Eastern Cape. Based on a study conducted by Muzangwa (2017), about 34.81% of smallholder farmers surveyed in the Eastern Cape produced under no-till, 25.93% practised crop rotation, while 22.22% retained crop residue in their fields. The farmers use a range of seeding and fertiliser planters such as hoes, animal-drawn planter, tractor-drawn planters and jab planters. Hoes are the most used planters by the smallholder farmers in the Eastern Cape. There are local companies in South Africa that are developing no-till planting machinery specifically for smallholder farmers, however this is still in its infancy.

The characteristics of adoption of CA among grain farmers in South Africa are further explained in Table 33.

Table 33: Characteristics of adoption among CA grain farmers in South Africa

Characteristics	Smallholder farmers	Commercial farmers
Adoption rate	Less than 5%	Approximately 15-20%
Adoption patterns	• Mostly older persons, pensioners and mostly women, which is synonymous with the profile of small-scale farmers. • More women in CA than conventional systems where men are responsible for ploughing and land preparation.	• More success in winter rainfall grain regions in Western Cape with 80% adoption. • In higher summer rainfall areas of KwaZulu-Natal, adoption rates vary between 60% and 70%. • Adoption in drier and sandier North West province is 20%. • Adoption in Free State is still very low, at less than 20%. • More interest in CA is emerging in higher rainfall regions in Mpumalanga, in the last decade.
Adoption of specific practices	• Little difference from certain traditional farming methods. • Where CA practices have significant financial requirements, small-scale farmers struggle to access finance and payback periods are too long.	• Approximately 40% that practise CA do crop rotation with three or more crops, 10% do monoculture, and 50% use two crops. • Annual cover crops used by 20% and 25% use perennial crops. • No-till planters are used by 36% of farmers, and 13% use disc planters.

Based on Smith *et al*. (2017)and WWF (2018).

The application of biofertilisers on smallholder farms is very low in Africa compared to other countries such as China, India and the USA. This has been attributed to lack of awareness, product inaccessibility, poor quality products, lack of technical experience and inadequate policies (Carvajal-Muñoz & Carmona-Garcia, 2012). Based on a study conducted among smallholder farmers in Gauteng province, about

95% of farmers surveyed had no knowledge of biofertilisers, and 65% were not familiar with the listed commercial biofertiliser products. This highlighted a need for increased awareness on the benefits of biofertilisers for complete uptake.

5.4.3.3. Market trends by commodity sub-sector

The uptake of conservation agriculture practices has largely been popular in the grain and field crops sub-sector. Commercial producers who farm maize, soybeans, wheat, barley and sunflowers in the Free State, Northern Cape and Western Cape provinces have increasingly adopted the approach. However, the CA principles are also applicable to the livestock and horticultural sub-sectors. According to Blignaut *et al.* (2015), feedlot cattle are more profitable under CA than the conventional production system, due to faster and more efficient growth. Likewise, the uptake of RA practices (cover crops, no-till and crop diversity) is increasing among fruit farmers. In orchards, regenerative agriculture is aimed at increasing soil organic matter and enhancing soil biodiversity using a diverse range of cover crops. ZZ2 a farming enterprise and fresh produce company operating across South Africa, notes that the application of regenerative agriculture in experimental orchards have shown an increase in soil carbon from 0.4% in 2003 to 4% in 2015 (Addison, 2019). In addition, the approach has resulted in improved soil health and improved water filtration.

Similarly, the use of biofertilisers have seen some uptake in the grain industry through cereal-legume intercropping systems. However, most of the application has been on research farms and the wider adoption is still limited.

5.4.4. Market barriers

The key market barriers and risks for conservation agriculture technologies are outlined below.

- The **long period for the benefits of CA to materialise** has been noted as a barrier to farmers. It takes about five to seven years for the transition to CA on farms and this period could have negative implications on yields and profit margins.
- **Lack of awareness on benefits of CA** farming practices. Although the adoption of conservation and regenerative agriculture is increasing, there are still a lot of farmers that are not aware of the principles. In the case of biofertilisers, most farmers are not aware of the benefits and the availability of the products. This drives a need for more training and education for farmers and extended trials so the benefits of the technologies can be realised.
- **High cost of equipment and limited financing options**
- **Volatile exchange rate** and associated price differences for imported farm machinery poses a risk for farmers that rely on imported equipment and machinery.

Table 34: Barriers experienced by different farm types

Commercial farmers	Smallholder farmers
• Lack of suitable planters for local conditions. • Lack of knowledge about implementing CA principles • High cost of imported equipment due to associated maintenance costs	• Lack of start-up capital to purchase CA equipment • Lack of knowledge and training on conservation agriculture practices and the associated benefits • Lack of access to equipment tailored to farm operations • Lack of an enabling policy environment • Limited access to markets discourage farmers to meaningfully adopt CA practices

Based on (WWF, 2018) and stakeholder engagements

5.4.5. Market opportunity

This section highlights the market growth potential for sustainable practices, the different factors that are likely to contribute to growth sustainable farming practices and technologies, and the market opportunity map.

5.4.5.1. Market size estimate

The cost[38] of no-till machinery ranges from R400 000 to R2.2 million, while planters targeted at small-scale farming sectors ranges from R1 000 to R37 000. Based on this information and the number of potential grain farming units (where the largest uptake of conservation agriculture has been observed) to adopt CA production, the current market size was determined. The estimated market size for no-till machinery is R4.48 billion, the formula used to determine the market size is shown below.

The biofertiliser market in South Africa was valued at R410 million in 2017 (Soumare, 2020).

Market size estimate = number of potential farming units x average cost of technology

[38] Identified from stakeholder engagements

Table 35: Market size and readiness level for conservation agriculture technologies

Innovation type	Market readiness	Potential farming units[39]	Market size[40]
No-till machinery	M-H	3424 (commercial)	R4.45 billion
		1711 (smallholder)	R32.52 million
		5135	R4.48 billion
Biofertilisers	L-M	R410 million[41] (2017) (Soumare et al., 2020)	

5.4.5.2. Market drivers

The market growth for sustainable agriculture practices can be attributed to the following drivers:

- **Climate change** and its adverse impacts on water resources is major driver for adoption of regenerative and conservation practices.
- The **reduced capital and operating costs**, sustained farm productivity and increased farmers profits are some of the major drivers to the uptake of sustainable agriculture practices
- The **carbon tax rate** is set at R120/tonne of CO_2e with a basic allowance of R48/tonne CO_2e. From 2022, farmers could be paying for both direct and indirect emissions. The indirect emission sources included in the Act relevant to the agriculture sector include electricity, diesel, petrol and N_2O emissions. Electricity accounts for about 48% of farm emissions followed by fuel ~28% and fertilizer at 20%. Given this, farmers are estimated to pay about R343/ha for indirect farm emissions[42]. The data on estimated carbon cost due to direct farm emissions is still limited. However, based on this data the use of low carbon alternatives such as biofertilisers could lower farm's carbon emissions (Bluenorth, 2016).
- The **emerging international trends** in carbon offset schemes to are likely to incentivise improved soil health could drive the uptake of sustainable practices.
- International policy regulations – stricter **measures on use of chemical fertilisers** are being imposed in countries like China and India. The Ministry of Agriculture in China introduced the "Zero Growth Policy of Pesticides and Fertilizers by 2020" in 2015, in order to phase out the use of synthetic pesticides and to promote the use of bio-based and organic pesticides and fertilisers. The European Union intends to **impose a carbon border mechanism** to inhibit carbon leakage through the European Green Deal. The mechanism intends to put a price on imports of emission-intensive goods into the EU. These policies have implications on farmers exporting to these countries and are likely to drive adoption of sustainable and bio-based technologies.

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39 Based on number of farming units determined in the commercial census 2017 (8559 farming units under cereal production) (StatsSA, 2020) and potential uptake of CA by 40% of commercial grain farmers and 20% smallholder grain farmers (based on WWF, 2018; Muzangwa, 2017). The potential uptake of CA was assumed to be driven by climate commitments from SA and climate financing options.

40 Market size determined based on number of potential farming units and average cost of implements. Small scale no-till planters cost on between R1000 and R37000 (average of R19 000), while no-till machinery cost between R400 000 and R2 200 000 (average of R1 300 000)

41 Estimated at USD 0.0293 billion which translates to R410 million (1USD = R13.98 average 2017 exchange rate).

42 Based on data South African fruit and wine data (Blue North, 2019)

5.4.5.3. Market growth potential

The market growth potential for conservation and regenerative agriculture practices lies in financial mechanisms and instruments that incentivize adoption and reduce the cost of transition to regenerative agriculture. A few of these noted in the literature are highlighted in Table 36:

Table 36: Financial instruments and mechanisms incentivising adoption of CA & RA

Financial instrument	Description	Source
Conservation stewardship programmes (CSPs)	Conservation Stewardship Programmes (CSPs). CSP's conservation agreement model offers direct incentives for conservation through a negotiated benefit package in return for conservation actions by communities. Thus, a conservation agreement links conservation funders — governments, bilateral agencies, private sector companies, foundations, individuals, etc. — to people who own and use natural resources. Benefits typically include investments in social services like health and education as well as investments in livelihoods, often in the agricultural or fisheries sectors. Benefits can also include direct payments and wages.	Conservation South Africa; Mudavanhu, 2015
Special purpose vehicle	A special purpose vehicle is a business that is initiated to carry out a specific activity. Integra Group is an example of such an entity that is set up to protect and broaden regenerative agriculture in South Africa. The entity is led by academics and farmers working on promoting regenerative agriculture. The group forms part of an ecosystem of stakeholders involved in the "Restore Africa fund". The fund aims to invest in climate smart regenerative agriculture practices.	Msimang, T (2020); Restore Africa (2020)
Carbon markets	Carbon markets aim to reduce greenhouse gas emissions by setting limits on emissions and enabling the trading of emission units. Recent developments have been made for incentivising adoption of regenerative agriculture practices through various carbon market platforms. A few examples of these are US based companies Indigo Agriculture (Indigo Carbon) and Nori. The growers registered on the platforms receive payouts for carbon credits generated.	Wozniacka, G (2020)

In addition, the growth of conservation and regenerative agriculture is likely to be a factor of growing market demand for key agricultural commodities such as grains (where the largest uptake of CA has been observed) and orchards. The grain market in South Africa is projected to register a CAGR of 5.9% during the period (2021-2026) (Mordor Intelligence, 2020). The projected trends for grain production and orchards are further highlighted in section 3 of the report.

The trends and drivers highlighted present an opportunity for application of no-till machinery and bio-based products in the transition to regenerative agriculture. As such, the market growth potential for no-till machinery is medium-to-high, while the market growth potential for biofertilisers is medium. The process of getting biofertilisers to market is largely dependent on the compliance and regulatory processes, which as noted can be a time consuming process, hence the medium growth potential. Given the market size and potential growth market for sustainable practices, a market opportunity map for sustainable agriculture technologies is shown below in Figure 45.

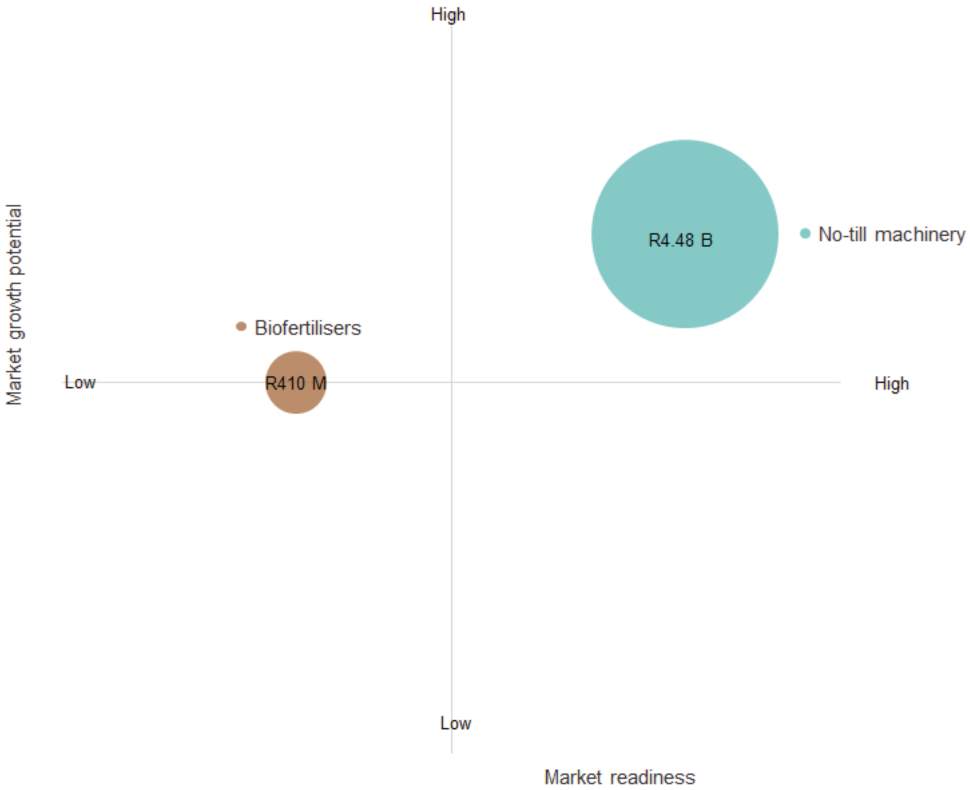

Figure 45: Market opportunity map for sustainable agriculture technologies

5.5. Drought tolerant crops

Biotechnology in food and agriculture can play a role in improving water use efficiency. Water can be retained at the plant root zone or through promoting plant canopy growth to cover the soil. This level of water efficiency can be achieved through conventional plant breeding techniques and biotechnology. In addition, alternative and indigenous crops are being explored for the adaptability to local climatic conditions. These crops are largely intended for dryland production where the variability of rainfall has more significant implications than irrigated crops. The market for the following water efficient and drought tolerant crops is explored:

- **Genetically modified (GM) or biotech crops**: Biotechnology is considered to be a promising means of developing new cultivars or crop types that are substantially more tolerant to droughts. Biotechnology in this context introduces transgenes that affect plant water use. This is also known as genetic engineering and results in the creation of genetically modified organisms (GMOs).
- **Underutilised indigenous crops**: Neglected underutilised species that are indigenous to South Africa include Amaranth, Bambara, Cowpea, Pearl Millet, Taro, Wild Mustard, and Wild Watermelon. These varietals have proven drought tolerant capabilities (Chivenge et al., 2015a).

These crops provide the introduction of alternative crops can that result in increased and improved water use efficiency and productivity.

5.5.1. Business case for drought tolerant crops

Drought tolerant crop varieties have potential to produce reliable yields under stressful climatic conditions. The breeding of drought tolerant crop varieties is noted to be a complex process. However, breeding techniques such as conventional breeding and marker-assisted selection have made some impact in the development of drought tolerant crop varieties. Drought tolerant crops such as maize, wheat and rice are commercially available in various countries.

The benefits of the crop varieties in comparison to traditional varieties are noted below:

- Maize varieties are highlighted to have increased productivity and yields of 30% to 50% more than traditional varieties under drought conditions.
- Wheat varieties are noted to perform better than other varieties by between 10% and 20% in arid conditions and up to 40% under very dry conditions.
- Rice variety released in India consumes up to 60% less water than traditional varieties (Tirado et al., 2010).

In South Africa, the varieties are not commercially available, thus the business case is still unclear.

Additionally, indigenous crops in South Africa have shown potential to be drought tolerant. Studies that have explored the water use efficiency for underutilised crops have shown that the crops are drought tolerant. A few examples of these crops include pearl millet, amaranth, cowpea or Taro (Chivenge et al., 2015b). Given the growing population growth, the water scarcity and climate change, these crops hold potential for increased food with limited use of natural resources.

5.5.2. Global market

A study conducted by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) notes the global status of commercialised biotech or GM crops in 2018. The relevant insights from the study are provided in this section.

The global area of biotech crops has increased from 1.7 million ha in 1996 to 191.7 million ha in 2018, increasing by 111%. A total of 70 countries across the globe adopted biotech crops of which 26 planted the crops and the remaining 44 imported the crops for food, feed and processing. The top five countries that have adopted biotech crops are shown in Figure 46.The USA has the highest area of biotech crops planted, followed by Brazil and Argentina. The five countries planted 91% of the total global biotech crop area in 2018 (ISAAA, 2018).

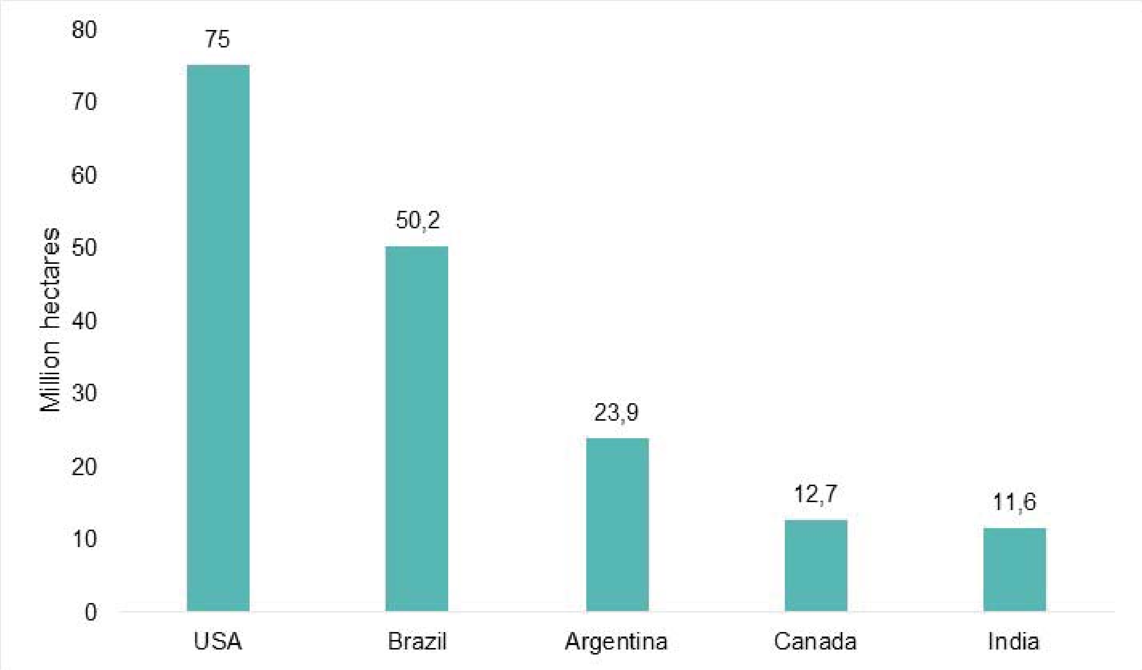

Figure 46: Top 5 countries that planted biotech crops in 2018

There are several biotech crops that are planted globally. The main crops planted are maize, soybeans, cotton and canola. However, more crops have been introduced such as alfalfa, sugar beets, papaya, apples, potatoes and squash. Indonesia has introduced the first drought-tolerant sugarcane in 2018. The main biotech crops planted in 2018 in area and adoption rate are illustrated in Figure 47. Soybeans have the largest area planted at 95.9 million ha and 50% adoption rate, followed by maize (58.9 million ha and 30.7% adoption rate) and canola (24.8 million ha and 13% adoption rate) (ISAAA, 2018).

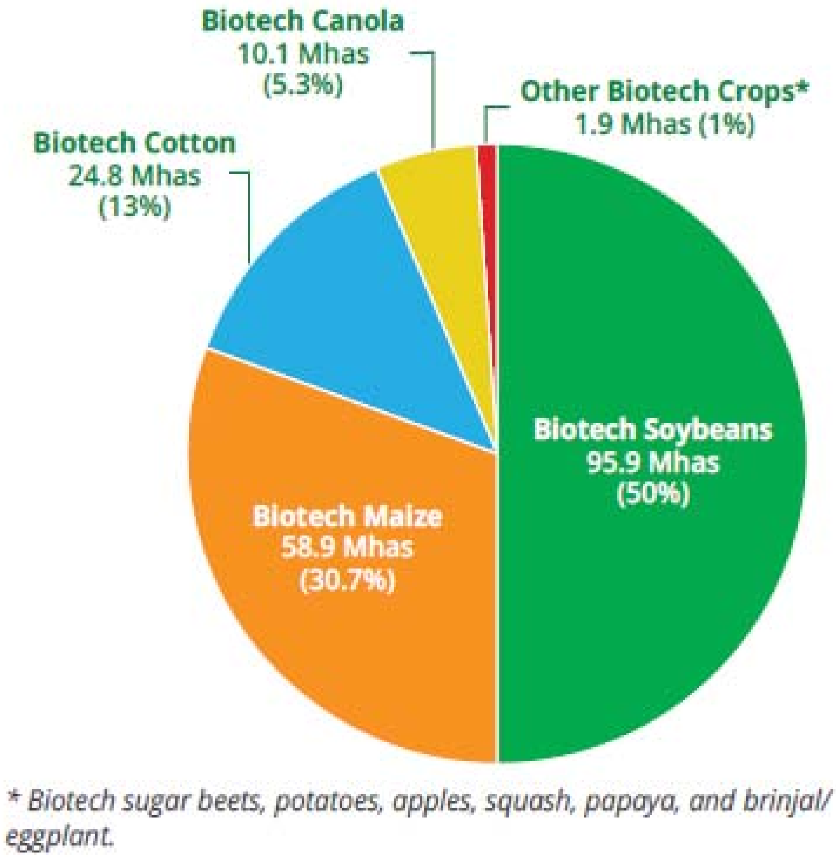

Figure 47: Biotech crops in 2018 (based on ISAAA, 2018)

In Africa, the potential for biotech crops is still quite high. There are only three countries with area planted under biotech crops. These are: eSwatini, Nigeria and South Africa. South Africa has the highest area of biotech crops planted. There are further countries such as Ethiopia, Kenya and Malawi that are in the process of granting environmental release approvals and working towards commercialisation of biotech crops.

The global market value for agriculture biotechnology was estimated at USD 27.78 billion in 2018 and is expected to increase at a CAGR of 10.10% during the period 2019-2022 (Grandview research, 2020b). There are several benefits can be attained from biotech crops, some of the noted benefits include increased crop productivity, reduced greenhouse gas emissions, contribution to food security and biodiversity conservation. The global economic grains contributed by biotech crops in the period 1996-2016 have amounted to USD 185.1 billion to more than 17 million farmers of which 95% came from developing countries (ISAAA, 2018).

5.5.3. South African market

This section highlights the market trends for biotech crops and underutilised indigenous crops. While previous sections highlighted the innovation market overview by farming type and commodity sub-sectors, this section only highlights the commodity trends. This is mainly due to the fact that most of crops are not yet commercially available and therefore the uptake among different farming segments is still limited.

5.5.3.1. Biotech crops market overview

The area under biotech crops production in South Africa remained unchanged since 2016, at 2.74 million ha. The main biotech crops are cotton, maize, and soya beans. The area planted under biotech cotton increased by 14% in 2018 from 37 406 ha to 42 654 ha. While the combined area of maize and soybeans slightly decreased. According to ISAAA (2018), most farmers in South Africa have adopted biotech crops with adoption percentages of 87% for biotech maize, 95% for biotech soya beans and 100% for biotech cotton (ISAAA, 2018).

Although the adoption of biotech crops is increasing in South Africa, most of the commercially available biotech crops are comprised of insect and herbicide resistant traits. The drought tolerance traits are mostly still researched or applied under field trials. South Africa is among the countries participating in the Water Efficient Maize for Africa (WEMA) project which was launched in 2008. The WEMA project is co-ordinated by the African Agricultural Technology Foundation (AATF) through a grant from the Bill and Melinda Gates Foundation. The project aims to provide smallholder farmers with drought and insect tolerant maize varieties. WEMA products are low-cost drought tolerant conventional (TEGO) and Genetically Modified (TELA) hybrids that give considerable yield advantage under moderate drought conditions. There's been several demonstration plots set-up in maize producing provinces across the country. The outcomes of the project are yet to be published. In addition, research is currently conducted for drought tolerant sugarcane varieties (ARC, 2020).

5.5.3.2. Underutilised indigenous crops market overview

Underutilised indigenous crops or traditional crops have been defined has crops that originated in a specific niche environment or have been cultivated over many years and adapted to the environment. These crops are not considered under the major crops, have low levels of utilisations and are mainly grown in small-scale farming areas (Modi & Mabhaudhi, 2016). The crops have largely been cultivated for subsistence or traditional medicine. Underutilised indigenous crops are also noted to be drought tolerant, some examples include Amaranths, Bambara groundnuts, Cowpea, Pearl Millet, Taro, Wild Mustard, and Wild Watermelon. The areas in which these crops are grown are shown in Table 37, most of the crops are grown in KwaZulu-Natal, Limpopo and Mpumalanga. There is no data available on the production levels of these crops.

Table 37: Production areas of indigenous crops

Crop	Crop type	Major production area in SA
Pearl Millet	Grain	Limpopo, KwaZulu-Natal and Free State
Cowpea	Grain	Limpopo, Gauteng, Mpumalanga, North West and KwaZulu-Natal provinces
Bambara groundnuts	Grain	Limpopo, Mpumalanga, North West, Gauteng and KwaZulu-Natal province
Amaranths	Vegetable	Limpopo, North West, Mpumalanga and KwaZulu-Natal
Taro	Vegetable	Mpumalanga and KwaZulu-Natal
Wild watermelon	Fruit	Can be found in the arid Kalahari region in the Northern Cape. It is also found growing or under cultivation in the Mpumalanga, North West, Limpopo, KwaZulu-Natal, Free State, Western Cape and Eastern Cape provinces.

Source: Based on DALRRD (2013)[43]

The use of underutilised indigenous crops is slowly increasing in South Africa. This has been observed in the agro-processing industry, where indigenous crops form part of the ingredients for healthier or ‘superfood’ products. The few examples include amaranth flour, nutrient boost powders or amaranth instant noodles. South Africa has an established commercial bioprospecting industry. Based on the bioprospecting regulatory framework, the term ‘bioprospecting’ is defined to include ‘any research on, or development or application of, indigenous biological resources for commercial or industrial exploitation’. Bioprospecting is about the processing of indigenous biological resources – that is, the ‘raw material’ up to the point where the resulting product is ready to be sold to consumers, but it does not include the sale itself. Given this and research conducted on bioprospecting in South Africa, bioprospecting products in South Africa can be found in five market segments namely: Cosmetics, oils, food flavourings, fragrances and medicine. A survey conducted across retail stores in the country found that 549 retail products contain South African indigenous plant resources and bee products. The plant resources included in these products were however, limited to only 24 South African plant species. The largest resource use in products was Aloe ferox, followed by bee products, rooibos and Pelargonium sidoide. Although the industry is currently focused on widely used or commercialised indigenous crops such as Buchu, Aloe., Rooibos tea or hoodia, it holds potential for underutilised indigenous crops (DEFF, 2012).

5.5.4. Market barriers

The barriers for drought tolerant crops and underutilised indigenous crops are provided in Table 38.

[43] Based on crop production guidelines available at: https://www.dalrrd.gov.za/

Table 38: Barriers for drought tolerant crops

Biotech crops	Underutilised indigenous crops
• Breeding represents a long term investment, in terms of both time and money. Although recent advances in maize breeding have reduced the time taken to develop new varieties, it still requires a minimum of six years • Legislation and regulations for GMO are not harmonised. • High regulatory barriers for product approval. • Technology develops ahead of policy, leading to delays in novel product approval. • Global markets are inaccessible due to weak networks and policy instruments.	• Social perceptions of underutilised crops as they considered as being “low status”, “backward” or “old fashioned” or “poor man’s” crops. • Lack of awareness information on their benefits is not easily accessible. • Insufficient, and at times lack of, propagation material and seed owing to informal seed market systems. • Insufficiently trained human resources who possess the technical aspects of producing underutilised crops. • Poor support from research and development into best management options with regards to the crop, soil, fertiliser and, pest and weed. • Long waiting time for permits to be issued.

Based on (Chivenge et al., 2015a; Masuka et al., 2017)

5.5.5. Market opportunity

This section highlights the market growth potential for drought tolerant crops, the different factors that are likely to contribute to growth of drought tolerant crops and the market opportunity map.

5.5.5.1. Market growth potential

There are currently no commercially available drought-tolerant crops. Thus, the market readiness for these crops is still quite low. However, the economic gains from biotech crops (insect and herbicide tolerant) in South Africa have been estimated to be over R2.91 billion[44] (AfricaBio, 2015).

In the case of underutilised crops, the bioprospecting market was estimated at R482 million in 2011, this was based on the total revenues generated in the primary and processing of indigenous resources. The total revenues generated from value-added products which contained bio-resources as an ingredient was valued at R1470 million in 2011 (DEFF, 2012). The value-added products were segmented into five product categories:

- Personal hygiene products (R585 million)
- Cosmetics (R555 million)
- Food flavourings (R110 million)
- Oils (R50 million)

The potential market for the bioprospecting industry was estimated at R2.5 billion per year based on resource permit application data (DEFF, 2012).

[44] Estimated at USD 219 million (1 USD = R13.25 at average 2015 exchange rate)

5.5.5.2. Market drivers

The potential drivers for drought tolerant crops are mainly regulatory. Some of the key policy regulations that could drive the uptake of drought tolerant crops are noted below:

- National Bioeconomy strategy: The objective of the strategy is to increase innovation in agricultural biosciences to ensure food security, enhance nutrition, improve health, expand and intensify agricultural production and processing. The strategy noted the importance of unlocking the value of indigenous crops coupled with consumer demand for natural products. The promotion and expansion of research and development for GM crops is further noted in the strategy.
- Legislative framework related to the National Environment Act: The Bioprospecting Access and Benefit-Sharing regulatory frameworks' objectives are the conservation of biological diversity; sustainable utilisation of indigenous biological resources; and the fair and equitable sharing of benefits among stakeholders, arising from bioprospecting involving indigenous biological resources. The framework provides guidelines for the commercialisation of indigenous product.

Other drivers include growing consumer demand for natural products, growing population and need to meet the growing food demand in water scare countries.

The market opportunity map for drought tolerant crops is shown in Figure 48. The potential for indigenous crops is much higher than for biotech crops. This is mainly because the indigenous crops are currently cultivated and require well-established value chains and seeds to be scaled in the market, while the drought tolerant traits for biotech crops are still being research. The growth of the biotech crop market is largely dependent on the expansion of research and development and loosened global regulations on biotech crops. As a result, the market growth potential for biotech crops is ranked low to medium, while indigenous crops are ranked medium to high market growth potential.

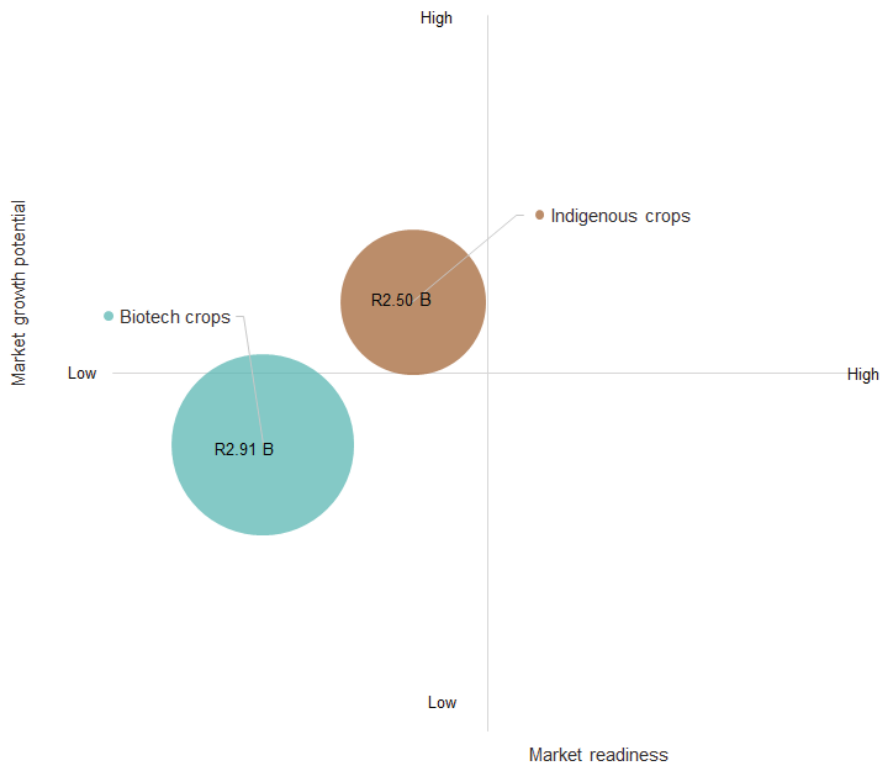

Figure 48: Market opportunity for drought tolerant crops

5.6. Summary of WSA innovations market analysis

A summary of the different WSA innovations including the market readiness, market size estimates, drivers, market growth potential and barriers is shown in Table 39.

Table 39: Summary analysis of WSA innovations

Innovation cluster	Technology	Market readiness[45]	Market size estimates	Market growth potential[46]	Market drivers	Market barriers	
						Commercial farmers	Smallholder farmers
Irrigation systems	Surface drip irrigation	H	The market size for surface drip irrigation systems was estimated at R1.48 billion per year	L-M	Policy related drivers (water policies and revitalisation of irrigation schemes)	• High maintenance costs • High investment costs • Limited technical knowledge and skills • Long return of investment (~7 years)	• Affordability of technology too high. • Poor performance of irrigation schemes due to poor infrastructure maintenance. • Lack of institutional support • Lack of extension and training.
	Sub-surface drip irrigation	H	The market size for sub-surface drip irrigation systems was estimated at R244,90 million per year	L-M			
	Low-flow drip irrigation	M	The market size for low-flow drip irrigation systems was estimated at R17.49 million per year	H			
Smart farming	Remote sensing services	M-H	The potential market was estimated at R671 billion (2017-2026) for digital technologies in the agriculture sector	H	Increasing farm operations International food standards and regulations Affordable technology Water scarcity	• Internet connectivity • Skills and knowledge gap • Cost of purchasing new technology and time invested in setting up farms	• There are barriers linked to affordability of innovations, access to inputs and lack of information. • There is reliance on extension officers to provide support on farm management and often there are limited number of officers and resources, which limits farmers'
	Sensor technology	M		M-H			
	Drones	M		M			

[45] The market readiness was defined according to Florin Paun (2012) which integrates demand readiness level scale and technology readiness. The stage of development of the technology was ranked as follows: high H) = standard technology and readily adopted; medium (M) = gaining traction; low (L) = recently commercialised.
[46] Market growth potential ranked as high (H), medium (M) or low (L) based on market trends and drivers of innovation

Innovation cluster	Technology	Market readiness[45]	Market size estimates	Market growth potential[46]	Market drivers	Market barriers	
						Commercial farmers	Smallholder farmers
			Market size for remote sensing services was estimated at R459 million Market size for soil sensors was estimated at R 2.89 billion The drone industry market was estimated at R2 billion (2017)			• Value of information collected to farmers • Lack of awareness on type of technology available and associated benefits	access to information. • Poor digital literacy • Lack of awareness on type of technology available and associated benefits
Undercover farming systems	Low and medium tech systems (i.e. shade nets and tunnels)	H	The estimated market size is R2.4 billion	M	Urbanisation Climate change and water scarcity Consumer preferences	• High initial investment costs especially for high-tech systems • Electricity costs due to high energy requirement from indoor farming systems • Access to land and suitable space • Limited technical skills and knowledge	• Access to markets. In cases where tunnel farms have been implemented at household level or at a small-scale, a key barrier noted was accessing markets. • Limited of technical skills and knowledge
	High-tech systems (i.e. greenhouses with soilless growing mediums)	M-H	The estimated market size is R11.78 billion	H			
Sustainable practices	No-till machinery	H	The estimated market size for no-till machinery is R4.48 billion	H	Financial benefits due to reduced operating costs Financial instruments from Banking Association of South Africa and Land Bank credit line ear-marked for climate smart agriculture incentivise adoption of sustainable practices	• Lack of awareness of benefits of conservation agriculture • The long period for the benefits of CA to materialise has been noted as a barrier to farmers. It takes about five to seven years for	• Lack of start-up capital to purchase CA equipment • Lack of knowledge and training on conservation agriculture practices and the associated benefits • Lack of access to equipment tailored to farm operations • Lack of an enabling policy
	Biofertilisers	L-M	R410 million (2017)	M			

Innovation cluster	Technology	Market readiness[45]	Market size estimates	Market growth potential[46]	Market drivers	Market barriers	
						Commercial farmers	**Smallholder farmers**
					International policy regulations on stricter measures for use of chemical fertiliser promote the use of bio-based and organic fertilisers	the transition to CA on farms and this period could have negative implications on yields and profit margins. • Lack of suitable planters for local conditions. • Lack of knowledge about implementing CA principles • High cost of imported equipment due to associated maintenance costs	environment • Limited access to markets discourage farmers to meaningfully adopt CA practices
Drought tolerant crops	Biotech crops	L	There are currently no commercially available drought-tolerant crops, however, the economic gains from biotech crops (insect and herbicide tolerant) in South Africa have been estimated to be over R2.91 billion	L-M	The drivers for drought tolerant crops are mainly regulatory. The policies that could drive the uptake of drought tolerant crops include the National bioeconomy strategy which makes mention of unlocking opportunities for indigenous products and expansion of research for GM crops	• Crop breeding represents a long term investment, in terms of both time and money. Although recent advances in maize breeding have reduced the time taken to develop new varieties, it still requires a minimum of six years • Global markets are inaccessible due to weak networks and policy instruments. • High regulatory barriers for product approval. • Social perceptions of underutilised crops as they considered as being “low status”, “backward” or “old fashioned” or “poor man’s” crops. • Insufficiently trained human resources who possess the technical aspects of producing underutilised crops.	
	Underutilised indigenous crops	L	The market size for the bioprospecting industry was estimated at R2.5 billion per year. This was based on the total revenues generated in the	M-H			

Innovation cluster	Technology	Market readiness[45]	Market size estimates	Market growth potential[46]	Market drivers	Market barriers	
						Commercial farmers	Smallholder farmers
			primary and processing of indigenous resources.				

5.7. Summary of WSA innovations market opportunities

The market opportunity and demand analysis section highlighted key opportunities from all the innovations in terms of the market growth potential. These are summarized below.

- A large number of WSA innovations have been observed in medium-to-large scale commercial farms, mainly due to significant economies of scale. The adoption of WSA technologies is still relatively low among smallholder and emerging farms. This presents an opportunity for WSA innovations to be disseminated to this market segment. However, the innovations would need to be fit for purpose and account for the context in which the farms operate.
- The market growth potential for WSA innovations is likely to be a factor of a growing demand for high value crops and increasing area under production. Therefore, high growth crops such as citrus, avocados, macadamia nuts, oilseeds and grains are attractive for WSA innovations. In addition, the growing niche market for crops such as mushrooms, micro-greens, or leafy greens driven by consumer preferences for fresh and plant-based foods, have the potential for increased growth in WSA innovations, especially high-tech undercover farming systems.
- High-tech undercover farming systems and no-till machinery currently present the highest market size estimate. This is mainly due to the high capital costs associated with the technologies which limits their uptake. In addition, most of the equipment and technologies is imported which has associated administrative costs to maintain the technologies. Therefore, there is an opportunity for local manufacturers to tap into this market and develop affordable and accessible equipment.
- The emerging and disruptive nature of smart farming technologies shows a high market growth potential, especially remote sensing services. Remote sensing services provide an opportunity for farms with existing infrastructure (hardware) to improve decision making processes and farm management. Whereas, for farms with no existing infrastructure, this service becomes an attractive add-on. Moreover, the interest in a centralized database for better farm management and decision making, becomes attractive for remote sensing services.
- Indigenous crops also hold a market growth potential due to the growing demand for natural products coupled with opportunities presented in the agro-processing sector. These crops are currently cultivated in South Africa, however, most are grown for subsistence or traditional medicines. Thus, the growth of the crops depends on the mechanisms that are implemented to remove the barriers that hinder their wide spread adoption.
- The African Continental Free Trade Agreement (AFCTA) provides opportunities for increased competitiveness in the agriculture sector. The removal of tariffs on 90% of the all goods traded will open up markets for agricultural products, with increased market access to countries like Nigeria, Angola and Senegal presenting opportunities for increased production of apples, oranges and wine grapes. This export market demand presents opportunities to leverage off WSA innovations for increased competitiveness.

- Stringent international climate strategies and ambitions (i.e. European Green deal and chemical fertilizer bans in countries like China and India) could further drive the uptake of WSA innovations, especially among export farmers.
- Nationally, regulatory instruments such as the carbon tax act which will include the agriculture sector in 2022 could drive the uptake of cleaner and efficient solutions such as biostimulants and regenerative agriculture.
- The closure of mines in Mpumalanga and current projects initiated to rehabilitate the mining land for agricultural production, present an opportunity for a transition to sustainable agricultural production. This creates an opportunity for integration of WSA innovations on this land.

Given these opportunities, a summary of the market opportunity map[47] is shown in Figure 49.

[47] The bubble size represents the market size estimate, the y-axis shows the market growth potential and the x-axis shows the market readiness of the different technologies.

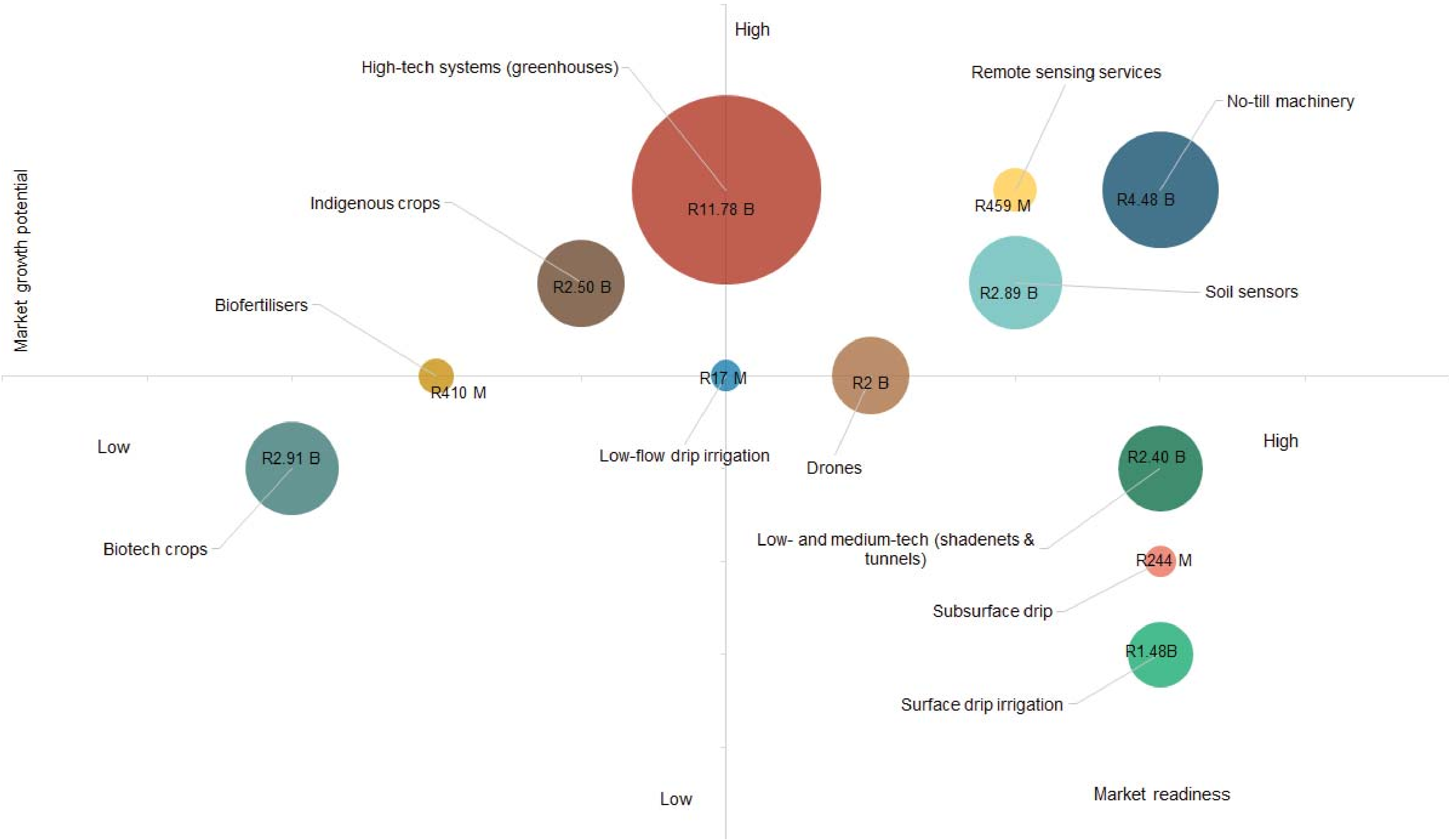

Figure 49: Market opportunity map for WSA innovations

6. Pathways for scaling WSA innovations

This section highlights some of the major barriers to the uptake of WSA innovations and the key developments needed remove the barriers and increase the uptake of WSA innovations.

6.1. Agricultural innovations systems

The performance of innovations is shaped by the different network of actors that operate in the innovation ecosystem. This has been embraced by the introduction of 'innovation systems'. The concept of innovation systems involves a range of public and private organisations, firms and individuals that demand and supply knowledge, technical and financial competencies. The system further involves the collaborative efforts from different stakeholders that interact in social, political and economic settings (Worldbank, 2007).

The agricultural innovation system (AIS) is comprised of four key components: agricultural research and education, business and enterprises, bridging institutions and the enabling environment. A diagram that illustrates the innovation system is noted in Figure 50. The actions and interactions of the different actors determines the degree to which innovations are effectively implemented and diffused into the market.

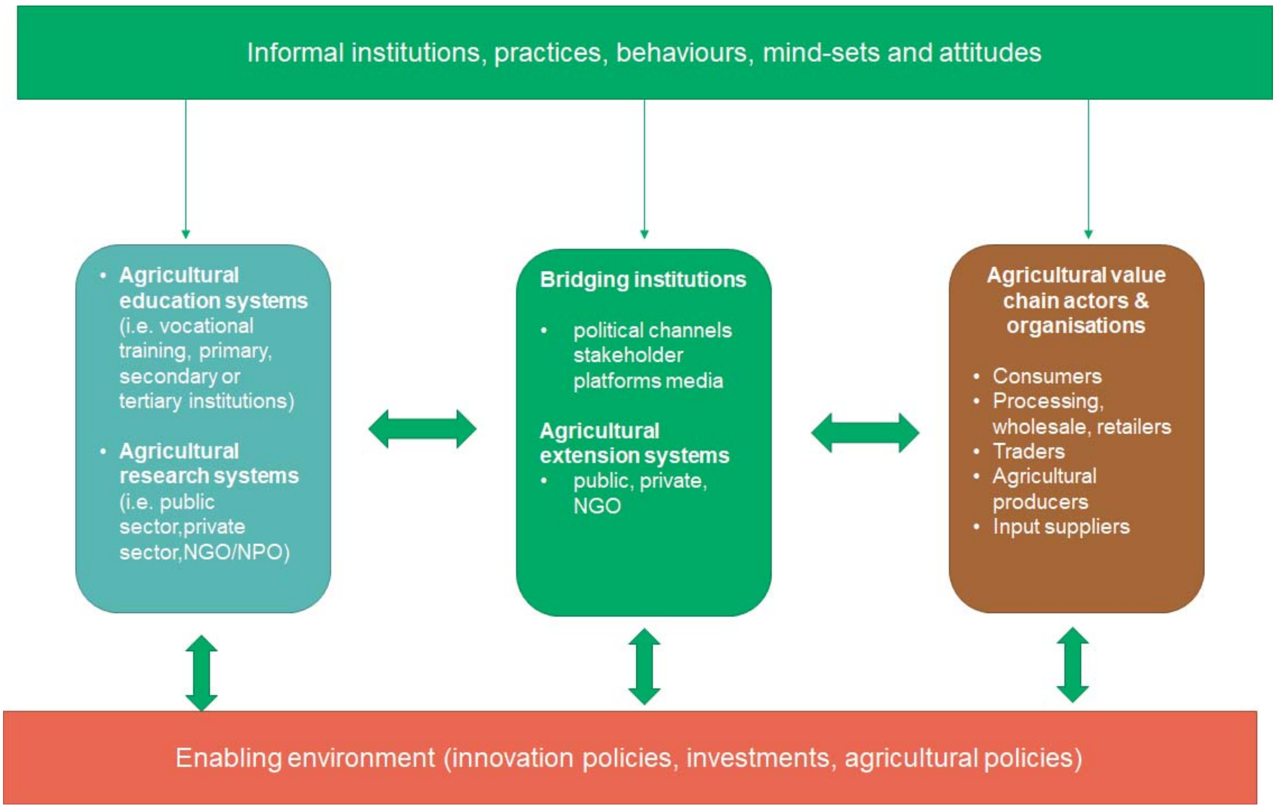

Figure 50: Agricultural innovation system – Adapted from (Aerni et al., 2015)

6.2. Barriers to the uptake of WSA innovations

The barriers to the uptake and diffusion of WSA innovations are underpinned by ineffective agricultural innovation systems or lack thereof. The major barriers to the uptake of WSA innovations vary from the demand and supply side actors. The barriers to the uptake of WSA innovations that have been encountered by demand-side actors or end-users (farmers) are noted in Table 40 below. While the barriers to the diffusion of WSA innovation highlighted from stakeholder engagements with technology providers are detailed in Table 41.

Table 40: Demand-side barriers to the uptake of WSA innovations

Barrier	Description
High cost of WSA technologies	Certain WSA innovations require a significant upfront investment that is not often possible for smaller farmers. In addition, the return on investment may take some time to realize, thereby reducing the likelihood that this outlay will be made, particularly in sectors that have low profit margins or are in decline.
Incremental value of innovation to farmer	Farming enterprises are faced with so many challenges that the decision to adopt a new technology needs to be aligned with their farm priorities and cash flow reserves.
Complexity of innovation	The user-friendliness of a technology is a key factor that determines whether farmers will adopt a technology. If a technology is too complex and costs a lot of time to apply, farmers are unlikely to adopt the technology.
Lack of awareness	There is a lack of awareness around the benefits, capabilities and business cases for new technology. The linkages between water use efficiency, energy efficiency, nutrient optimization and land productivity is poorly understood, yet is highly relevant in understanding the business case behind some of the WSA innovations.
Limited technical skills and knowledge	There is a lack of local skills and knowledge for many WSA innovations, especially technical skills in the development of farming technologies. This can result in sub-optimal operation of the WSA innovations, thereby undermining their effectiveness, while also limiting the roll-out of these innovations
Price of water	The low cost of water for farmers undermines the business case for investment in WSA innovations. The cost of irrigation water varies across the country but it is considered to be very low and is subsidized by other users. As noted above, the driver for WSA innovation is more likely to be

	energy costs, not water. In cases where energy and water usage are not linked (particularly dryland agriculture), the low or zero cost of water may reduce the incentive for efficiency investments.
Economies of scale	The feasibility of water-smart innovations differs between smallholder and commercial farmers. The economies of scale of a technology offered to a specific farmer group and the uptake might vary based on the resources (i.e. financial or social capital) currently available. Smallholder farmers generally face numerous challenges to adoption of technology including: the lack of credit worthiness; market access; no collaterals; affordability; lack of technical skills; and lack of appropriate infrastructure, including electricity and dams.

Table 41: Supply-side barriers to the diffusion of WSA innovations

Barrier	Description
Accessing finance for full commercialization of innovations	Businesses interviewed noted that although there might be funding for technology development and commercialisation, funding or support for business-related expenses is often not accounted for, which limits operations and growth of the business.
Limited access to markets	There are several technologies that have been introduced but have failed to be adopted by famers. Mainly because the technology did not align with their farm priorities. Additionally, if it is a new technology that is not widely adopted it becomes a challenge to convince farmers to adopt it unless leading farmers within their network have already implemented it and are reaping the benefits.
Lack of networking and collaborating platforms	Lack of networking platforms for smoother collaboration with players operating in this space (such as farmers, funders, incubators, regulatory bodies, or research institutions). A challenge highlighted is that start-up companies operate with a range of different institutions and stakeholders with different governing mandates. The various processes and systems that start-up companies have to adhere to has cost implications, which for a business with limited cash-flow becomes unsustainable.
Stringent licensing and compliance processes	The regulatory environment is unfriendly for the diffusion of technology especially for small businesses. Most water smart agriculture innovators have to adhere to compliance processes and protocols which often take a long time or have delays and result in administrative burden and costs, which limits the scaling and diffusion of WSA innovations.
Competition with imported low-cost technologies	A key challenge noted by local equipment manufacturers is that they struggle to convince farmers from purchasing cheaper and imported machinery, which hinders and limits the uptake of locally produced equipment. Thus, this creates a need for greater support systems for local innovations for manufacturers to become more price competitive.

6.3. Pathways for scaling WSA innovations

This section highlights the key developments needed to unlock the barriers that hinder the uptake of WSA innovations both from the supply and demand-side actors.

6.3.1. Demand-side interventions

Given the barriers highlighted in the preceding section to the uptake of WSA innovations, the stakeholders interviewed noted key developments needed to increase the diffusion of WSA innovations. These are outlined in Table 42.

Table 42: Key developments to the uptake of WSA innovations

Barrier	Proposed development
Market access & value of innovation to farmer	• Government support programmes to incentivise adoption of water smart technologies. • Piloting the technology through farmer associations and irrigation boards to share with their members. • Aligning and tailoring the value proposition of the innovation between the innovator and end-user and taking into account the different contexts in which farms operate. This can take form of demand or user-led research.
High capital cost	• Preferential financing should be offered by financial institutions to farmers who invest in WSA innovations. Notably, the term of the debt could be adjusted to allow for the maturation of the benefits from these investments in order to promote their uptake, whilst improving their financial resilience. • Shift in mindset towards value proposition thinking and better understanding of the business case. • Promotion of incentive based financing mechanisms, where known WSA innovation off-takers are incentivised for adoption. In doing so, the early adopters can promote the innovation within their networks. • There is a need for more impact investors to de-risk loans offered from local commercial banks. • Development of OPEX-based models or leasing options for agricultural equipment (e.g. Axl app from AFGRI)
Limited technical skills and knowledge	• Initiating mentorship programmes where emerging farmers are guided and supported by established commercial farmers. • Targeted training on the different WSA technologies • Webinars, symposiums and workshops that are frequent and freely available to all farming types
Limited awareness	• Developing tools and training modules that highlight water risks to farmers and support farm level water balance decision-making • Utilising existing platforms from agricultural associations and networks • Disseminate information on WSA innovations through discussion platforms such as smart water indaba
Price of water	• Linking water use thresholds into finance instruments to incentivise reduced consumption and increased re-use
Access to finance	• Utilising larger farming cooperatives (co-ops) as a mechanism for administering loans for WSA equipment or tech. If large deals between co-ops and commercial banks are struck, lower interest rates could possibly be offered if scale can be achieved.

6.3.2. Supply-side interventions

Table 43 highlights some of the interventions that can support the diffusion of WSA innovations into the market.

Table 43: Key developments to the diffusion of WSA innovations

Barrier	Proposed development
Accessing finance for full commercialisations of innovations	• Life-cycle support for early stage businesses. More long-term support from all players is needed for early stage businesses due to the time it takes (estimated at a minimum of 5 years and beyond) to commercialise WSA technologies. Moreover, the role of government has been highlighted as a key enabler for greater diffusion of innovations. This has been alluded to in the form of removing regulatory barriers and creating an enabling environment for increased adoption
Limited access to markets	• Access to innovative marketing and piloting platforms that can reach both smallholder and commercial farmers have been as a key area to increased uptake of WSA innovations. • A different model of agricultural extension for marketing innovations to smallholder farmers
Lack of networking and collaborating platforms	• Increased collaboration among actors. The linkages to the different actors along the WSA innovation value chain are critical to ensuring the path to commercialisation of WSA innovations. This could take the form of a networking platform which could provide information on the players that add value in the agriculture sector and provide opportunities for increased collaboration.
Stringent licensing and compliance processes	• Capacity building and support to policy makers to improve productivity and efficiency.
Competition with imported low-cost technologies	• Increased government support for water smart agricultural innovations through tax incentives or rebates. • The media has a role to play in promoting local brands and changing the perception around local products.

6.3.3. WSA innovation case studies

This section highlights some national and international case studies on interventions that led to the successful diffusion of WSA innovations.

6.3.3.1. Multi-stakeholder initiative – Nestlé Maggi Morogo instant noodles

A public-private partnership between Nestlé South Africa, the Council for Scientific and Industrial Research (CSIR), the Agricultural Research Council (ARC), the University of Fort Hare and the Department of Science and Innovation (DSI) led to the launch of a new instant noodle product with the local indigenous amaranthus ('*morogo*') plant. The partnership involved a three-year extensive research program in indigenous African leafy vegetables (cleome, cowpea and amaranthus) in South Africa to assess their nutrient bioavailability during digestion. The research results indicated that amaranthus showed proven health benefits and thus the selected choice for product development.

The nature of the partnership comprised:

- The ARC and University of Fort Hare exploring the cultivation methods of *morogo* and evaluating sustainable methods for commercial and smallholder farmers to produce the vegetable under irrigated conditions.
- The CSIR with its advanced research technology to convert the fresh *morogo* into a powder form while maintaining its quality and nutrients.
- Nestlé leveraging off its consumer insights and product development to manufacture the final instant noodle *morogo* product.

The product is expected to benefit local farming communities, especially small-scale farmers and contribute to local economic development. The launch of this product highlights the importance of multi-stakeholder collaboration in the diffusion of innovations.

6.3.3.2. Innovative finance models for improved water efficiency measures

- Nedbank, a financial services group in South Africa, developed an innovative financing solution to support farmers directly with sustainable farming solutions. A shade netting financing plan has been developed to assist farmers to protect their margins against the effects of climate change.
  The financing plan extends over five years and enable farmers to install shade nets without placing their cash flow under pressure. The financing plan is offered to existing and new customers. As a result of the new financing solution, uptake of shade netting has been observed among farmer organisations such as the Humansdorp Co-op and Overberg Agri.

- AFGRI Agri services launched a farming equipment sharing platform in 2020 called Axl. The platform aims to increase access to farm machinery to farmers, especially those with limited capital to invest in farm equipment. The benefits of the platform are that it:
  - allows farmers to find, rent and pay for agricultural equipment through a secure online portal,

    - enables service providers, equipment owners, retailers and contractors to grow additional revenue streams and offset costs of maintenance,
    - provides small, emerging or large commercial farmers with access to agricultural equipment at a lower cost.

- SunCulture, a company based in Nairobi provides tailor made solar irrigation solutions and a "Pay-As-You-Grow" financing model to provide solar powered irrigation at an affordable rate for smallholder farmers in sub-Saharan Africa. The Pay-As-You-Grow option allows farmers to pay for the technology in small monthly installments. This financing option and the tailor made solar irrigation solutions addresses the affordability and financing limitations that most smallholder farmers experience.

6.3.3.3. Tool for scaling water management technologies

The International Water Management Institute (IWMI) developed a tool that aims to guide implementers (i.e. government representatives, private sector actors and donors) in designing scaling strategies that are adaptive to a specific context and the resources available. The tool guides users through a series of structured steps to carry out an analysis to identify enablers and hinderers influencing farmers' adoption of irrigation and water management technologies in a specific context. It is aimed at improving the understanding of the enabling environment for water solutions and the system dynamics in scaling water management innovations.

In the context of the agricultural value chain, the enabling environment is comprised of a set of policies, informal institutions, support services and conditions that create and maintain a general operational environment. The analysis is expected to result in country-specific solutions and programs to scale water innovations.

7. Recommendations

This report highlighted key WSA innovations that could play a role in addressing the water scarcity challenges in the South Africa agriculture sector. It highlighted the current market trends, growth potential and opportunities of the different WSA innovations. While the identified technologies hold potential, there are significant barriers that hinder the uptake and diffusion of the technologies.

The barriers highlighted in the report are largely driven by inefficient agricultural innovation systems. Therefore, the recommended next steps for increased diffusion and uptake of water smart agricultural innovations are detailed below. These can be implemented by key players that operate within the water and agricultural ecosystem and are underpinned by a **collective effort** of the different role players.

7.1. Development of innovative financing models

Based on the insights gathered, it is clear that finance is a major barrier to the uptake and diffusion of WSA innovations. Therefore, there is a need for innovative financing models to be implemented and incentive based finance systems to be in place. Moreover, it is crucial to re-think the business models and support services of the different innovations and the degree to which they add value to the different farming types (smallholder to established commercial farms). Proposed actions to achieve these include:

- Formulating partnerships between innovators and financial institutions to develop innovative financing options for agricultural innovations (examples could include innovative leasing and rental options for farms with limited cash flows). This partnership can be formulated through Development finance institutions (DFIs) or commercial banks and institutions that represent WSA innovators. These institutions can include the South African Irrigation Institute (SABI), AgriSA, Agricultural Business Chamber or the South African Agricultural Machinery Association (SAMA) or innovation entities (i.e. Technology innovation agency or Department of Science and Innovation).
- Research to further understand effective financial and business model scenarios to diffuse WSA innovations to the different farm types, especially emerging and smallholder farms.
- Establishing more blended finance options similar to the recent Agri-industrial fund between the Industrial Development Corporation (IDC) and the Department of Agriculture Land Reform and Rural Development (DALRRD) to de-risk loans for WSA innovations.

7.2. Increased awareness and value of innovations to farmers

While there is some uptake of WSA innovations in South Africa, some of these are not tailored to address the needs of the farmers. This is partly due to limited communication and collaboration between innovators and end-users. Thus, innovators should work collaboratively with farmers to align the innovations to the needs and values of the famers. This collaboration can further provide a platform to increase awareness on the benefits of the different innovations. The key actions to implement these are:

- WSA innovation entities could leverage off existing platforms from producer associations such as farmer information days, auctions and exhibitions to establish discussion and piloting platforms to effectively develop appropriate solutions that meet the needs of the farmers.
- Scaling decision support tools that highlight water risks to farmers and provide support on farm level water balance decision-making. Examples of these have been developed or are being developed by a range of institutions such as the Council for Scientific and Industrial Research (CSIR) and several university institutions through support from the Water Research Commission (WRC).

7.3. Increased training and mentorship opportunities

Limited skills and knowledge related to the use of the technologies is another barrier to the uptake of WSA innovations. Frequent training and accessible platforms are needed to increase the uptake of innovations. Proposed actions to achieve this include:

- Establishing platforms to provide training and awareness of the different innovations (i.e. seminars, workshops or freely accessible online tools). Online tools and seminars could be hosted and developed by institutions such as the WRC.
- Integrating WSA innovations into incubation and agricultural training programmes. The trainings can be aligned to skills programmes such as Agriculture Sector Education Training Authority (AgriSETA) or Energy & Water Sector Education Training Authority (EWSETA).
- Developing mentorship programmes on WSA innovations that facilitates knowledge exchange between established commercial farms, emerging and smallholder farms. The mentorship programmes can be facilitated by producer associations or incubation programmes that support agribusinesses.

7.4. Increased government support

Market entry and access is a key challenge that most businesses face when trying to scale their innovations and this is partly due to an unfriendly regulatory environment. Thus, the government has a role to play in providing an enabling environment for increased adoption of WSA innovations. Proposed actions are:

- Incentives for adoption and promotion of WSA innovations such as tax rebates or incentives.
- Strengthening collaboration between relevant government departments (such as Department of Agriculture Land Reform and Rural Development, Department of Water Affairs and Sanitation, Department of Science and Innovation, Department of Trade Industry and Competition).
- Incorporating water smart agriculture into government strategies and policies (i.e. Agriculture and agro-processing masterplan).

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Annex 1: Relevant WSA innovation institutions in South Africa

Table 44 below list some of the main players in the Water Smart Agriculture ecosystem.

Table 44: List of main players in WSA innovation ecosystem

Type of Institution	Institution
Government	Department of Trade and Industry & Competition
	Department of Agriculture, Land Reform, & Rural Development
	National Agricultural Marketing Council
	Department of Water and Sanitation
	Department of Environment, Forestry and Fisheries
	Department of Science and Innovation
Research	Agriculture Research Council
	Water Research Commission
	Council for Scientific and Industrial Research (CSIR)
	Universities (University of Cape Town, University of Pretoria, University of the Western Cape, University of KwaZulu-Natal, University of Free State, etc.)
Union & Industry associations	GrainSA, Citrus group association, Subtropical association, VinPro, South African Table Wine Association
	AgriSA, African farmers association of South Africa, Transvaal agricultural union, National African Farmers Union of South Africa, Agricultural Business Chamber South Africa
Water innovations associations	South African Irrigation Institute, Couth African Agricultural Machinery Association (SAMA), Technology and Innovation Agency
Irrigation systems providers	Netafim
	Agriplas Automation
	Cherry irrigation
	Aquacheck
Smart farming technology providers	Mezzanine
	Aerobotics
	Aquacheck
	DFS software
	Agritechnovation
	FarmPin
Undercover farming system providers	Haygrove
	VegTech2000, Dynatrade, Kibboe
	Greenhouses, Hytech Agriculture
	Netafim, Stelza
	Hygrotech
Sustainable farming machinery and product	AgCO Corporation
	Agri Supplies

Type of Institution	Institution
manufacturers	AGRICO
	Madumbi
Training and skills programmes	AgriSETA, EWSETA, Fetola, Launchlab
Finance	Landbank, Industrial Development Corporation, Micro-Agricultural Financial Institutions of South Africa

Type of institution	Institution
Government	Department of Trade and Industry & Competition
	Department of Agriculture, Land Reform, & Rural Development
	National Treasury & SARS
	National Agricultural Marketing Council
	Department of Water and Sanitation
	Department of Environment, Forestry and Fisheries
	Department of Science and Innovation
Research	Agriculture Research Council
	Water Research Commission
	CSIR
	Universities (University of Cape Town, University of Pretoria, University of the Western Cape, University of KwaZulu-Natal, University of Free State, etc.)
Union & Industry associations	GrainSA, Citrus group association, Subtropical association, AgriSA, African farmers association of South Africa, Transvaal agricultural union, National African Farmers Union of South Africa, Agricultural Business Chamber South African
Water innovations associations	South African Irrigation Institute, SAMMA
Training programmes	AgriSETA, EWSETA, Fetola, Launchlab
Finance	Landbank, Industrial Development Corporation, Micro-Agricultural Financial Institutions of South Africa

Annex 2: Relevant policies and regulatory instruments

There are several policies in the South African agriculture and water sectors that govern the agriculture sector and influence the uptake of water smart innovations. A few of these policies are highlighted in Table 45.

Table 45: Key policies and legislation relevant to water smart agriculture

Name of policy	Relevance of policy to water smart agriculture
The National Development Plan 2030 (NDP 2012)	• Highlights plans to expand irrigated agriculture and develop new water schemes • Highlights plans to support local and sectoral efforts to reduce water demand and improve water-use efficiency • Highlighting the importance of agriculture to the green economy
The Agriculture Integrated Growth and Development Plan (IGDP 2012)	• Plans to develop equitable, productive, competitive, profitable and sustainable agriculture, forestry and fisheries sectors • Emphasises that the sector needs to benefit all South Africans
The Agricultural Policy Action Plan (APAP 2014)	• A programmatic response to key policy documents, including the National Development Plan (NDP) and the New Growth Path (NGP)
National Water Act, Act No 36 of 1998 (NWA 1998)	• Regulates and protects water resources including surface water and groundwater
The National Environmental Management Act 107 of 1998 (NEMA 1998)	• NEMA is the overarching legislative framework for environmental governance. Core values are reflected through the following principles: • Environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably • Development must be environmentally, socially and economically sustainable
National Climate Change Adaptation Strategy (2019)	• Support to farmers to implement more efficient climate-smart and conservation practices • Promotion of urban agriculture, including community and household food gardens in areas not classified as agricultural land • Increasing the role of agricultural extension officers in supporting vulnerable farmers • Promotion and subsidisation of water conservation technologies
Integrated Resources Plan (IRP) 2019	• The IRP is an electricity infrastructure development plan based on least-cost electricity supply and demand balance, taking into account security of supply and the environment (minimize negative emissions and water usage).
National Bioeconomy Strategy	• Highlights strategic interventions in the agriculture sector and enhance competitiveness • Plans to unlock value of indigenous crops • Plans to establish a network of agro-innovation hubs that

	enhance technology transfer and extension
Drafted polices	
Draft Conservation Agriculture Policy (2017)	• To promote and establish ecologically and economically sustainable agricultural systems to increase food security. • Recommending government to offer producers with incentives to adopt conservation agriculture measures thereby developing incentive schemes, and that tax rebates are provided to manufacturers of conservation agriculture equipment.
Draft Climate change bill (2018)	• To provide management of climate change impacts and identify new industrial opportunities in the growth of the green economy. • Enhance adaptive capacity of the country and increase reduce vulnerability from climate change • Contribute to global efforts to reduce greenhouse gas emissions.
Draft Climate Smart Agriculture Framework Policy (2018)	• To outline the role of climate smart agriculture (CSA) practices in addressing climate change related vulnerabilities facing the agricultural sector. • Highlight the importance of integrating mitigation and adaptation strategies into production systems and the need for resource investment into indigenous knowledge systems. • To guide government, investors and developmental partners in integrating CSA within projects and programmes.