

THE STATE OF CLIMATE SMART REGENERATIVE AGRICULTURE IN SOUTH AFRICA



The state of climate smart regenerative agriculture in South Africa

A report prepared by ASSET Research

Upon request of the Office of the Agricultural Counsellor, Economic Affairs, Embassy of the
Kingdom of the Netherlands
and Grain South Africa

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July 2025

Acknowledgement

ASSET Research would like to acknowledge the funding received from the Agricultural Counsellor, Economic Affairs of the Embassy of the Kingdom of the Netherlands, and Grain SA Group of Entities and specifically the Commercial Producers Trust. This support is gratefully acknowledged. The inputs received from William Bowden, Timo Cober and Godfrey Kgatle is specifically recognised.

ASSET Research is also deeply indebted to the providers of information, data and guidance from various subject specialists and stakeholders. Your commitment and contribution have enriched the report greatly. Ms Leandri van Elst's assistance with the editing, layout and artwork is also greatly appreciated.

Lastly, ASSET Research would also like to thank the farmers who have participated in the research, who provided information and who was willing to engage with us on this journey. Farmers provide the food that allows society to think, act and celebrate life.

While many people have contributed to the report, ASSET Research remains responsible for the contents contained therein.

Recommended citation:

Blignaut, J.N., Smith, H., Blignaut, L.J., Erasmus, L., Herold, K. and Maluleke, M. 2025. *The state of climate smart regenerative agriculture in South Africa*. Pretoria: ASSET Research.

Executive summary

Scope and aim

The Netherlands Agriculture Network (LAN), at the Netherlands Embassy in Pretoria, requested the compilation of a comprehensive report on the state of climate smart regenerative agriculture (CSRA) with the aim to create an overview of CSRA in South Africa. This needed to include the benefits, crop types, practices, drivers of change and gaps or challenges that prevent wider adoption. The report serves as a foundation for shaping future cooperation between South Africa and the Netherlands in CSRA, aimed at sharing knowledge, addressing challenges and fostering innovation in sustainable farming practices.

Definition (Chapter 0)

CSRA is applied in various combinations and to systems that have the same or related goal of making the agricultural sector more sustainable and resilient. These include, but is not limited to, regenerative agriculture (RA), climate smart agriculture (CSA), agroecology, conservation agriculture (CA), organic agriculture, agroforestry, permaculture and biodynamic farming. Herein CSRA is used as an umbrella term encapsulating all of these. The major principles and practices are highlighted in Figures E.1 and E.2.

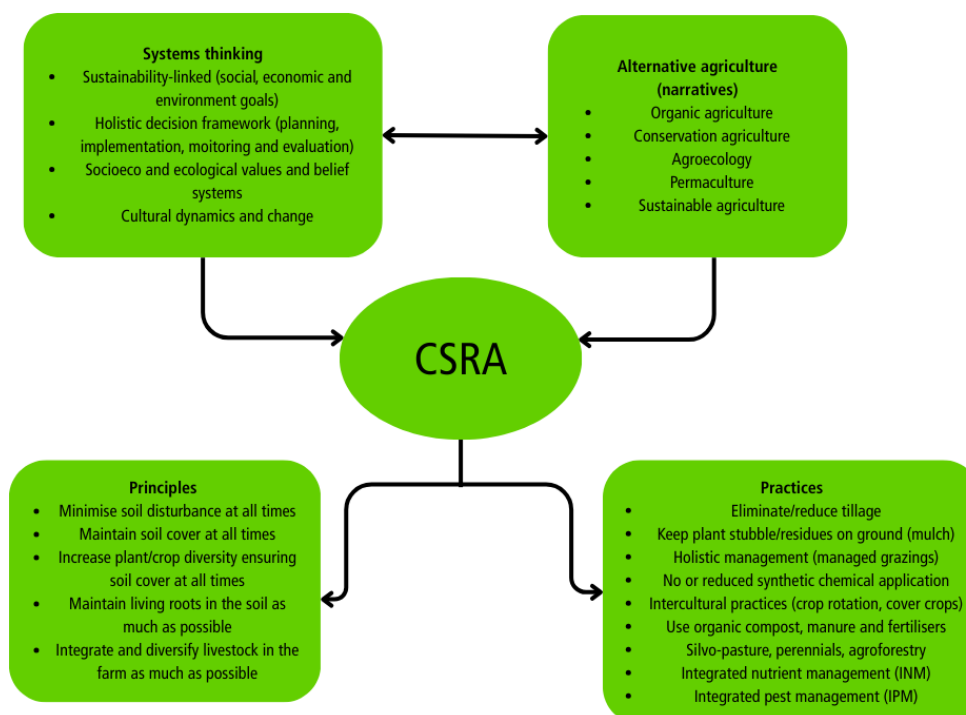


Figure E.1 Key systems, principles and practices through which CSRA has emerged

Source: Adapted from Rai et al. (2025)

It should be stressed that CSRA is an approach and process, not a recipe, that combines ongoing learning processes, continuous adaptation and the application of several principles as discussed in Chapter 0 and Annexures 1 and 2. The multi-faceted benefits of CSRA as a climate change adaptation and mitigation measure are linked to the enhanced soil quality, the drawdown of atmospheric carbon, the development and enhancement of system-wide resilience and productivity as well as improved water retention capacity. Correctly applied principles and practices, as shown in Figure E.2, are the core of CSRA – it can be complemented and combined with other approaches to farming, such as organic farming, agroforestry, permaculture, etc. as highlighted above.

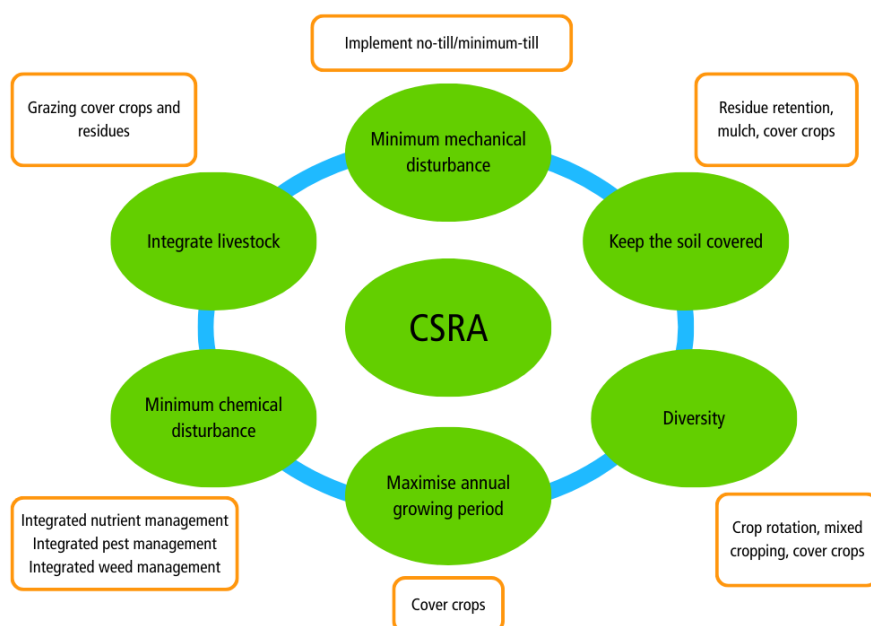


Figure E.2 CSRA principles (in green) and practices (in orange)

Grain crops (Chapters 1–3)

Smith (2021) found that CA is practiced on 25% of the total area under commercial annual crop-livestock systems, as indicated in Table E.1. This increased from 23% in 2015. It is important to note here that the definition of CA used above falls under the umbrella of CSRA.

Table E.1 The percentage adoption of CA

PROVINCE	Total annual crop area (ha)	Area under CA in 2021 (ha)	Area under CA in 2015 (ha)	CA adoption in 2021 (%)	CA adoption in 2015 (%)
Western Cape	1 569 277	804 866	564 940	51%	36%
North West	890 437	330 464	142 470	37%	16%
Mpumalanga	850 484	205 598	314 679	24%	37%
Free State	2 196 986	73 520	175 759	3%	8%
KwaZulu-Natal	164 620	62 956	82 310	38%	50%
Limpopo	255 866	68 834	63 967	27%	25%
Gauteng	173 435	57 649	116 202	33%	67%
Eastern Cape	160 307	3 194	0	2%	0%
Northern Cape	69 498	0	7 645	0%	11%
TOTAL	6 330 910	1 607 081	1 467 971	25%	23%

Source: Smith (2021)

To grow the adoption of CSRA, a systems approach is required to facilitate and support farmers to make transformational change, and to bridge the so-called investment- or J-curve, from traditional harmful conventional systems to CA/RA principles and practices. This transformation process requires critical attention to all the elements of the 360-degree solution (see Figure E.3), such as human capacity, infrastructure development, capital investments and institutional support.

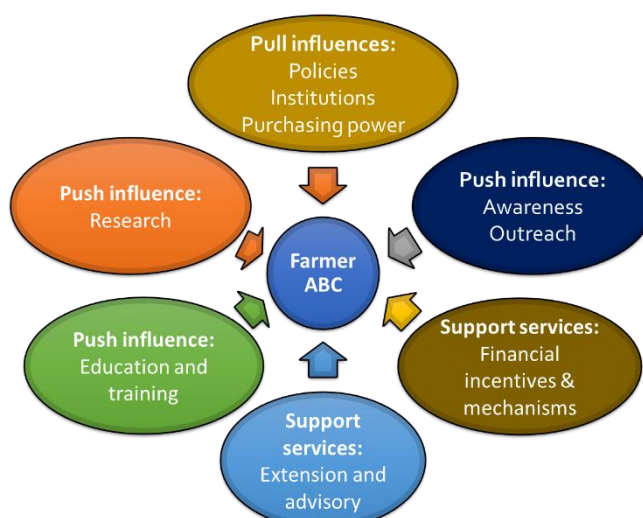


Figure E.3 A 360-degree solution to support farmers' transition to CA/RA

Livestock (Chapters 4–6)

While acknowledging various weakness in the data, emerging evidence suggests that 25–35% of livestock operations have implemented some form of climate smart practice (see Table E.2). Within these many progressive operations not only implement baseline climate smart techniques but also integrate more targeted resilience and sustainability actions. Among the climate smart adopters are the following:

1. Conservation grazing

Approximately 40–50% of those already climate smart may be employing targeted conservation grazing practices. This suggests about 10–17.5% of all commercial livestock operations are actively using conservation grazing as part of their climate strategy.

2. Conservation agriculture practices

When considering the integration of conservation agriculture principles within a livestock context (e.g. reduced tillage in forage production, cover cropping in integrated systems), about 35–45% of climate smart adopters might be using these practices. This roughly translates to 8.75–15.75% of the entire commercial population.

3. Integrated resilience and sustainability

When multiple interventions are combined, such as precision livestock management alongside conservation grazing and CA principles, the estimated share of farmers achieving a robust resilience profile might be in the range of 15–25% of commercial operations.

Note: Given overlaps (many farmers may employ both conservation grazing and CA/RA measures), these numbers are best seen as complementary slices of the broader climate smart pie. The different categories include climate smart practices, resilient and sustainable farming, conservation agriculture and conservation grazing.

Table E.2 *Visualising the adoption of conservation livestock production summarising the above indicative rates*

Category	Estimated adoption rate (of total commercial farms)	Comments
Overall climate smart adoption	25–35%	Encompasses a wide range of climate smart practices.
Among climate smart adopters		
Conservation grazing	40–50% of climate-smart adopters (≈ 10–17.5% overall)	Focuses on rotational/optimised grazing to enhance ecosystem resilience.
Conservation agriculture practices	35–40% of climate-smart adopters (≈ 8.75–15.75% overall)	Integrates practices like minimal tillage, permanent soil cover and rotations.
Integrated resilience and sustainability	~15–25%	Represents operations combining multiple measures into a robust system.

Maree et al. (2025) summarised the costs and benefits of the different grazing systems as illustrated in Figure E.4. The general benefits noted with respect to adaptive grazing (i.e. grazing methods that embraces one or other facet of CSRA within extensive livestock production systems) includes increases in soil organic carbon, soil fertility, more standing biomass, improved nutrient cycling, a reduction in soil erosion, etc.

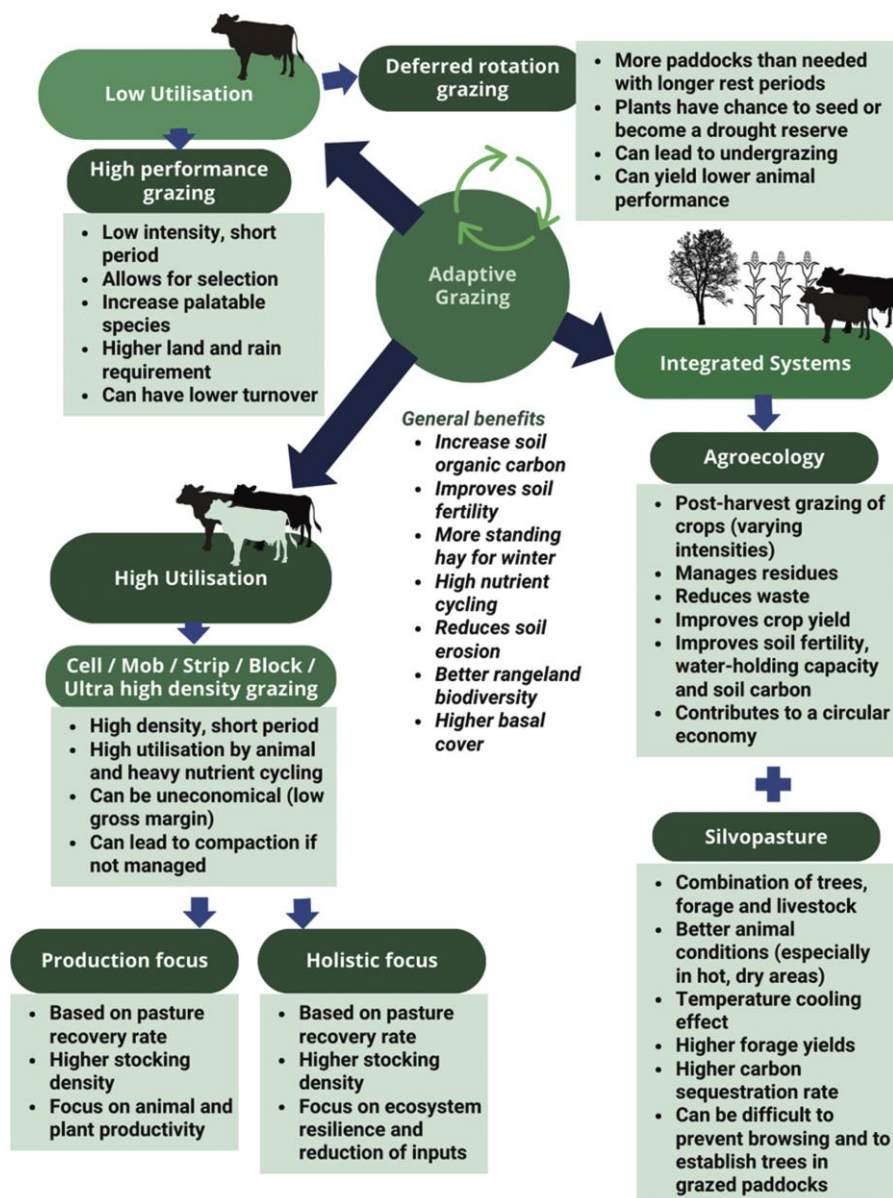


Figure E.4 Cost and benefits of adaptive grazing

Source: Maree et al. (2025)

Horticulture (Chapters 7–9)

While little is known about the degree to which CSRA has been adopted in South Africa, the benefits thereof are well documented through a large cross-section of case studies. Some of these benefits are highlighted in Figure E.5 and include the reduction in the need to use pesticides, the reduction in damage to crops and the environment, the promotion of healthy crops and plants, and the reduction in potential water and air contaminants.

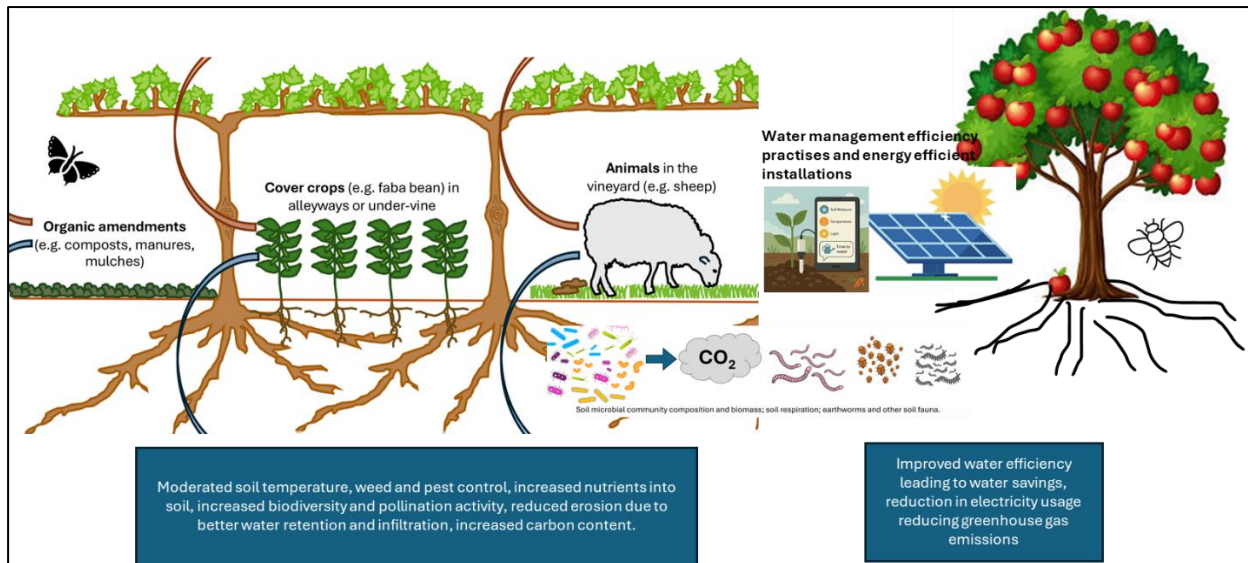


Figure E.5 Illustration of the environmental benefits of CRSA practices within horticulture

Source: Adapted from O'Brian et al. (2025)

Dutch investments in South African agriculture (Chapter 10)

The agricultural sector in South Africa has significantly benefited from Dutch investments, which have helped modernise farming practices, improve infrastructure and drive technological innovation. Dutch foreign direct investment (FDI) has played a crucial role in revitalising South Africa's agricultural and horticultural industries by supporting both public infrastructure projects and private-sector partnerships. In 2022, the Netherlands accounted for 36.7% of South Africa's total inward FDI stock, making it the largest single investor in the country (Trade.mu 2023). These investment benefit flows are as shown in Figure E.6 (Netherlands Enterprise Agency 2023; DTIC 2023; WUR 2023; Van der Merwe et al. 2023). These investments have not only benefited South African farmers but have also contributed to job creation, economic growth and food security in the country. Moving forward, the continued partnership between Dutch investors and South African stakeholders will be crucial in addressing ongoing challenges such as climate change, water scarcity, market access, biodiversity preservation, reverse export flows and opportunities, and others.

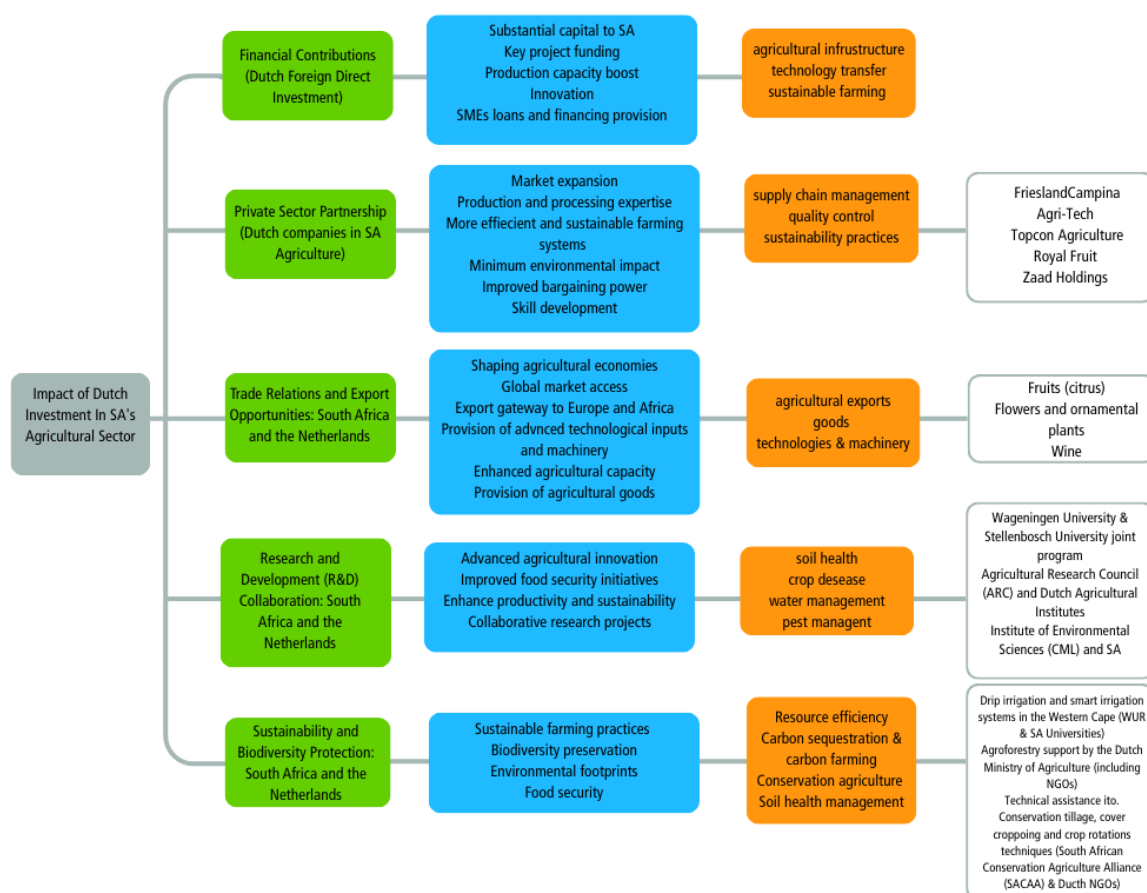


Figure E.6 Dutch investments in South African agricultural sector

Challenges and opportunities (Chapter 11)

To advance CSRA in South Africa, several challenges must be overcome and the opportunities that exist must be developed. These can be categorised, irrespective of the branch of agriculture, in four interrelated themes as detailed in Chapter 11. The themes and their respective sub-headings are as follows:

1. Finances, funding mechanisms and access to resources

Challenges

A mismatch between private costs and public benefits

A mismatch between short-term needs and long-term benefits

A mismatch between bio-physical and research needs and financial demands

Opportunities

Development of a finance programme that targets CSRA adoption, products and services by means of:

- CSRA finance and investment accelerator for producers
- CSRA finance and investment accelerator for agri-businesses

2. Training, awareness, capacity and research

Challenges

Scale or size of the operation

Academic level and type of training

Scope of research

Opportunities

Development of a joint research and training curricula and awareness programme promoting CSRA by means of:

- On-farm CSRA training, research and awareness programme
- CSRA industry training, research and awareness programme

3. Trade and value chain related matters

Challenges

Certification and regulation

Value chain channels

Beneficiation

Opportunities

Development of a mutually beneficial CSRA trade and exchange programme by means of:

- Product differentiation
- Value chain development

4. Technology

Challenges

The need to overcome several financial and technological barriers

Opportunities

Development of bespoke CSRA technologies by means of:

- Exploring various software options
- Investing in several hardware options

Table of contents

Executive summary	iv
INTRODUCTION	1
Chapter 0 Climate smart regenerative agriculture	2
0.1 Background	2
0.2 Umbrella term and definition.....	3
0.3 Key principles of CSRA	5
Part A GRAIN PRODUCTION IN SOUTH AFRICA.....	11
Chapter 1 An overview of grain crop production in South Africa	12
1.1 Introduction	12
1.2 Challenges faced in the grain farming industry.....	19
1.3 The key role players contributing to growing CSRA	20
Chapter 2 Climate smart regenerative grain crop production: Evidence from the field.....	22
2.1 Adoption of climate smart regenerative agriculture	22
2.2 Grains and cereals in other branches of agriculture	24
2.3 Case studies on the adoption of climate smart regenerative agriculture	25
2.4 Training and extension strategy for farmer support and resilience on CSRA in the grain crop industry	31
Chapter 3 The cost and benefits of CSRA within grain crop production	34
3.1 Reasoning behind the move from conventional to climate smart regenerative agriculture.....	34
3.2 Benefits of climate smart regenerative agriculture.....	34
Part B LIVESTOCK PRODUCTION IN SOUTH AFRICA	51
Chapter 4 An overview of livestock production in South Africa	52
4.1 Introduction	52
4.2 Different segments within the livestock sector.....	55
Chapter 5 Climate smart regenerative livestock production: Evidence from the field.....	60
5.1 Introduction	60
5.2 Overview of adoption	60
5.3 Supportive information for the mindset of the South African agricultural sector	61
5.4 Case studies about conservation agriculture in South Africa	63
Chapter 6 The cost and benefits of CSRA within livestock production	74
6.1 Introduction	74
6.2 Environmental	77

6.3	Financial	78
6.4	Social	79
6.5	Reflecting on methane emissions within the livestock sector	80
Part C HORTICULTURE PRODUCTION IN SOUTH AFRICA		86
Chapter 7	An overview of horticulture production in South Africa	87
7.1	Overview	87
7.2	Viticulture and table grapes	90
7.3	Fruit and nuts	90
7.4	Vegetables.....	91
7.5	Other horticultural produce	92
Chapter 8	Climate smart regenerative horticulture production: Evidence from the field.....	93
8.1	Environmental certifications	93
8.2	Industry platforms	95
8.3	Case Studies of climate smart regenerative agriculture practices within horticulture ...	96
Chapter 9	The cost and benefits of CSRA within horticulture production	106
9.1	Introduction	106
9.2	Environmental benefits.....	106
9.3	Environmental costs	110
9.4	Financial benefits.....	111
9.5	Financial costs	113
9.6	Social benefits	115
9.7	Social costs	117
Part D INSTITUTIONAL ANALYSIS		118
Chapter 10	Overview and importance of South Africa–Netherlands bilateral collaboration in agriculture	119
10.1	Historical overview of the relationship in agriculture between South Africa and the Netherlands.....	119
10.2	Agricultural and horticultural landscape of South Africa and the Netherlands	119
10.3	Key areas of collaboration.....	120
10.4	Bilateral agreements.....	121
10.5	Dutch investments in South Africa’s agricultural sector	126
10.6	Future prospects and opportunities	126
10.7	Challenges and obstacles to collaboration	128
10.8	Key stakeholder identification, roles and interest mapping	129
10.9	Interest, influence and engagement analysis.....	132
10.10	Stakeholder perception, sentiments and concerns about CSRA.....	133

10.11	Network analysis	134
Part E DISCUSSION AND CONCLUSION		138
Chapter 11 Advancing climate smart regenerative agriculture: challenges and opportunities		139
11.1	Introduction	139
11.2	Finances, funding and access to resources	139
11.3	Training, awareness, capacity and research	142
11.4	Trade and value chain related matters	145
11.5	Technology	148
References – Chapter 0		150
References – Part A		153
References – Part B		155
References – Part C		157
References – Part D		163
ANNEXURE 1: A DESCRIPTION OF DIFFERENT SUSTAINABLE AND RESILIENT AGRICULTURAL CONCEPTS AND SYSTEMS		168
ANNEXURE 2: DESCRIPTION OF KEY CSRA PRINCIPLES		174
ANNEXURE 3: DESCRIPTION OF KEY CSRA PRACTICES		177
ANNEXURE 3A: A comparative analysis of different sustainable and resilient agricultural systems.		187
ANNEXURE 4: Part A, Grain crops		193
ANNEXURE 5: Livestock production in South Africa: Production areas, trends, consumption, market structure, trade of different sectors		204
ANNEXURE 6: Details of horticulture sub-branches		231
ANNEXURE 7: Network Analysis.....		268

List of Tables

Table E.1	The percentage adoption of CA	vi
Table E.2	Visualising the adoption of conservation livestock production summarising the above indicative rates	vii
Table 0.1	The transition stages towards CSRA.....	4
Table 1.1	A shortlist of key role players in the grain industry	21
Table 2.1	The percentage adoption of CA	23
Table 4.1	Summary of the trade between the Netherlands and South Africa	58
Table 4.2	Estimated livestock numbers in 2020 (millions)	59
Table 5.1	Visualising the adoption of conservation livestock production summarising the above indicative rates	61

Table 5.2	Proposed circular economy interventions for the agricultural sector	62
Table 6.1	Cost and benefits of various grazing systems: Results from a global survey	75
Table 6.2	Summary of CSRA practices and technologies for land-based systems, their impact on food security, climate change adaptation and mitigation, and the main constraints to their adoption.....	76
Table 6.3	Rangeland condition and gross margins as influenced by grazing capacity	77
Table 6.4	Differences in the digestive tracks of humans, dogs and ruminants	81
Table 6.5	Climate smart livestock practices.....	84
Table 9.1	Motivation for adopting cover crops within horticultural farms.....	107
Table 9.2	Perceived impact of cover crops on farmers' net profit within horticulture	111
Table 10.1	Significant areas of collaboration between South Africa and the Netherlands.....	121
Table 10.2	Agriculture and horticulture bilateral agreements between South Africa, the Netherlands and EU	123
Table 10.3	Key interest that drive the motivations and goals of each stakeholder/institution category	131
Table 10.4	Key CSRA activities	135

List of Figures

Figure E.1	Key systems, principles and practices through which CSRA has emerged	iv
Figure E.2	CSRA principles (in green) and practices (in orange)	v
Figure E.3	A 360-degree solution to support farmers' transition to CA/RA	vi
Figure E.4	Cost and benefits of adaptive grazing	viii
Figure E.5	Illustration of the environmental benefits of CRSA practices within horticulture.....	ix
Figure E.6	Dutch investments in South African agricultural sector	x
Figure 0.1	Key systems, principles and practices through which CSRA has emerged	5
Figure 0.2	CSRA principles (in green) and practices (in orange)	7
Figure 0.3	Soil health	8
Figure 0.4	Benefits and outcomes of regenerative agriculture	10
Figure 1.1	Grain crop production as part of various other agricultural industries across South Africa based on climatologically suitable areas	13
Figure 1.2	Change in area planted with summer and winter crops	14
Figure 1.3	Change in tonnes harvested	14
Figure 1.4	The gross value of agricultural production.....	15
Figure 1.5	The contribution of the field crop sector to the national agricultural sector.....	16
Figure 1.6	% VAT contribution of different sectors	16
Figure 1.7	The gross and net income in the agriculture sector.....	17

Figure 1.8	Increase in producer price over time	17
Figure 1.9	Number of people employed in the agricultural sector	18
Figure 1.10	Value of exported grain	19
Figure 1.11	Value of imported grain.....	19
Figure 1.12	Value of exported oilseeds	19
Figure 1.13	Value of imported oilseeds.....	19
Figure 1.14	Fertiliser prices, 2021–2024.....	20
Figure 2.1	Adoption percentages of CA	23
Figure 2.2	How the maize fields looked in 2019, the year the Mandys fully adopted NT, interseeding and winter cover crops	25
Figure 2.3	Interseeding in 2024. Note the difference in ground cover and the cover crops planted in between the rows.....	26
Figure 2.4	A 360-degree solution to support farmers’ transition to CA/RA	32
Figure 3.1	Benefits of/motivation for the adoption of CSRA	35
Figure 3.2	The benefits and interaction of CA principles.....	35
Figure 3.3	The benefits and interaction of RA principles.....	36
Figure 3.4	An illustration of how the possible benefits is organised into the environmental, social and financial categories	36
Figure 3.5	Minimum soil disturbance or no-tillage immediately arrests this prime cause of the downward cycle of soil degradation.....	37
Figure 3.6	Keep the soil covered with living or dead plants	37
Figure 3.7	Current CO ₂ emissions for each system vs. the sequestration potential of transitioning to CSRA/FCA farming systems for maize per region in South Africa	38
Figure 3.8	Different SOC sequestration potentials under different maize-based systems in the North West Province of South Africa	39
Figure 3.9	Crop rotation/intercropping / cover crops have multiple functions and benefits and could rightly be seen as the driver of CSRA	40
Figure 3.10	Integrating cropping and livestock systems have benefits both in terms of crop and of animal production.	40
Figure 3.11	Liquid carbon exuded by living roots feed the soil food web.	41
Figure 3.12	The perception of profitability of CSRA and CT among farmers.....	42
Figure 3.13	The duration of time it took before farmers observed any positive changes or benefits following the initial dip in productivity or income	43
Figure 3.14	General challenges faced during the transition period	48
Figure 3.15	Level of difficulty farmers faced with different CA practices during the transition period	49
Figure 3.16	How farmers managed to overcome the above challenges during the transition phase (J- curve)	49

Figure 3.17	Support and resources most helpful for information and advice during the transition process	50
Figure 4.1	Volume index of agricultural production, 2019/20–2023/24.....	53
Figure 4.2	Gross income (R million) from agricultural sectors, 2022/23–2023/24.....	54
Figure 4.3	Classification of major livestock sectors	56
Figure 4.4	Livestock percentages in different provinces	56
Figure 4.5	Export percentages of livestock to other countries	56
Figure 4.6	Import percentages of livestock into South Africa.....	57
Figure 4.7	Classification of other livestock sectors	58
Figure 5.1	Extent to which circular economy interventions can benefit the agriculture and food sector	63
Figure 5.2	State of readiness and of implementation of circular economy interventions in South Africa.....	63
Figure 6.1	Cost and benefits of adaptive grazing	74
Figure 6.3	Comparative analysis in profitability and production between two regenerative farmers and the South African average	79
Figure 6.4	Relative contributions of animal species, emission sources and gases to the total livestock greenhouse gas emissions in the African continent.....	80
Figure 6.5	An overview of nine FAO studies conducted in various regions and countries to identify and evaluate low-cost strategies to improve productivity while reducing livestock GHG emissions.....	85
Figure 7.1	Contribution of horticulture as a percentage of total agriculture gross value, 2009–2023	87
Figure 7.2	Percentage breakdown of area under horticulture	88
Figure 7.3	Export value in R' billion of fresh fruit and vegetables to the Netherlands, UK and other countries, 2013–2022	88
Figure 7.4	Breakdown of horticulture gross value per category according to DALRRD	89
Figure 7.5	The 'top 10' horticultural produce based on value of production and total tonnage produced, 2023	90
Figure 7.6	Break-down of fruit sector by production volume and value.....	91
Figure 8.1	Key principles of SIZA environmental certification	93
Figure 8.2	Breakdown of SIZA environmental certification records by commodities.....	94
Figure 8.3	Left: Indigenous grass species planted between vineyards at Saltare's MCC vineyards; Right: Nativo's "weeds in bloom" cover crops	97
Figure 8.4	Mr Breytenbach among the vineyards	99
Figure 8.5	Tomatoes and avocados under minimum tillage at ZZ2	100
Figure 8.6	Field preparation at Klipopmekaar Rooibos Farm	100
Figure 8.7	Integrated grazing at Wellington Farm	101

Figure 8.8	Mulching	103
Figure 8.9	Drip irrigation on new orchards	103
Figure 8.10	Netting	104
Figure 8.11	Wheat straw for mulch (left) and netting over fruit trees (right)	104
Figure 8.12	CCC Benchmark analysis showing where emissions are generated at farm level	105
Figure 8.13	Trellis design at Boschendal farm that reaps carbon emission and cost savings	105
Figure 9.1	Illustration of the environmental benefits of CRSA practises within horticulture	110
Figure 9.2	Mindmap showing initial findings of the benefits of cover crops within orchards taken from four year trial in the Warm and Koue Bokkeveld that can be translated into financial cost savings	112
Figure 9.3	Carbon Calculator by CCC Initiative Benchmark Report 2022 for Pome Fruit.	113
Figure 10.1	Dutch investments in South African agricultural sector	126
Figure 10.2	Challenges and obstacles in the Dutch-South African collaboration	129
Figure 10.3	Institutional and stakeholder roles	130
Figure 10.4	Institutional and stakeholder perceptions and sentiments about CSRA.....	133
Figure 10.5	Institutional and stakeholder concerns about CSRA	133



INTRODUCTION

Chapter 0 Climate smart regenerative agriculture

0.1 Background

Conventional industrial agriculture has played a vital role in feeding the growing world population. This has resulted in enhanced food security, with undernourishment rates dropping globally from 14.7% in 2000 to 9.9% in 2020. This success was achieved through various advancements, including mechanisation, synthetic agrochemicals, improved crop varieties and intensive practices in monoculture cropping, and was assisted by distribution chain enhancements. However, the extensive use of tillage, synthetic agrochemicals and fossil fuels strains food systems through environmental repercussions such as soil degradation, water pollution, pest resistance, greenhouse gas emissions and reliance on non-renewable energy sources. Furthermore, driven by the projected global population of 8.6 billion by 2030, the intensified practices of conventional industrial agriculture exacerbate resource exploitation and environmental degradation, posing significant sustainability challenges in meeting the surging food demand. This has sparked increased interest in the development of more sustainable and resilient farming systems and practices that restore and protect the environment while reviving human societies and economies. Various agricultural systems, such as climate smart and regenerative agriculture (CSRA) offer the synergistic potential of the restoration and conservation of people, planet and profit. However, despite their potential benefits, adopting CSRA can be challenged by transition periods, initial costs, yield variability, risk management, economic viability, ambiguous standards and the need for farmers to acquire new knowledge and skills. Understanding and supporting the transformation to CSRA is, therefore, vital for its widespread adoption (Jayasinghe et al. 2023).

According to O'Connor (2020), regeneration is both a new and very old paradigm, built upon centuries old indigenous wisdom that has been married with our current scientific understanding and innovations. For thousands of years, farmers have provided humanity with sustenance and nutrition, developing creative and progressive techniques that work with nature, not against it. But the regenerative agriculture (RA) term remained relatively fringe until the mid-2010s where it has seen a demonstrable rise in publicity and popularity. News mentions of RA have doubled every year since 2015, and from a total of seven academic publications on RA between 1986 and 2016, 52 were published between 2016 and 2020. The term RA is also being increasingly used by various governments and agri-food corporations in their sustainable agriculture programmes and policies. Furthermore, RA is not a specific practice but rather an ethos focused on sustainable techniques, encompassing a spectrum that ranges from foundational beliefs to well-validated practices (Jayasinghe et al. 2023).

From a climate perspective, agriculture contributes directly and indirectly to about a third of the greenhouse gas emissions. Agriculture today is already suffering from climate change worldwide from extreme climatic events, resulting in production losses – drought spells, torrential rains and floods, cold and heat waves. With this, agriculture as done today is NOT climate smart. “Business as usual” will not give the right answers and a new strong emphasis on climate smart agriculture (CSA) is needed (CSA guide web portal: <https://csaguide.cgiar.org/csa/about-this-website>).

0.2 Umbrella term and definition

In this report, climate smart regenerative agriculture (CSRA) is proposed as an **umbrella term** to encompass various sustainable and resilient agricultural terms, concepts and systems. Right now, there are several concepts and terms used to describe agricultural systems that have socio-ecological and economic (people, planet and profit) goals, such as conservation agriculture, climate smart agriculture, carbon farming, organic and agroecological farming – a comprehensive list is shown and discussed below and in Annexure 1. This broad range of terms are used arbitrarily, and at times it can be confusing to tell the differences between them. This uncertainty hinders researchers' ability to effect progress and policy formulation, and farmers' ability to adopt and adapt them. Moreover, the ambiguity surrounding the term can mislead consumers and enable unethical commercial promotion (e.g. green-washing).

Although these different concepts are not entirely similar there is enough common ground (or a common goal) to group them together under an umbrella term. The concepts differ in their implementation frameworks, objectives and in the degree of system redesign and consideration of ecological, economic and social outcomes (see below and in Annexures 1 to 3 for a more detailed description of the different concepts, principles and practices).

This report does not suggest that one concept is in any way more correct, better or preferable to other concepts. Rather, this report highlights the range of choices, or a basket of principles, practices and technologies, that decision-makers might consider when engaging with ideas, policies and practices, and for pragmatic purposes we suggest the use of climate smart regenerative agriculture (CSRA) as an umbrella term. The rise to prominence of RA and CSRA and the gaps they address do not necessarily mean that the other sustainable agriculture narratives (systems) described here are no longer relevant, or that there must be one unifying narrative to the exclusion of all others. Scoones et al. (2020) emphasise the importance of a plurality of pathways for transformations, that “no matter how specific the context, there is never only one relevant, viable path”. A plurality of sustainable agriculture narratives could provide the opportunity for an inclusive dialogue which gives space for a variety of perspectives, experiences, knowledges and actors in the agri-food system, which could help to navigate the transformation towards a sustainable agri-food system, but only if equity, justice and diversity are central to this transformation pathway (Bless, Davila & Plant 2023).

The common ground or goal all these systems have is that they all support the agricultural sector to be more sustainable and resilient, with the intent to look beyond yield numbers and focus more on a systems-based (holistic) approach. While the overall goal is similar, these concepts fall along a continuum of practices farmers can implement to transition into a more sustainable system in any given context. Table 0.1 shows this transition from conventional till to CSRA as an illustration of how this transition works. How each of the principles are implemented changes over time and place, as the health of degraded soils is restored and farmers' awareness and knowledge improve, which are all part of a unique on-farm context. Table 0.1 also illustrates how the so-called “sustainability level” of a farm increase with the implementation of the CSRA principles.

Table 0.1 The transition stages towards CSRA

Stage	1	2	3	4	5	6	7
Farming system	Conventional tillage	Min. or reduced tillage	Conv. NT	Conv. Zero till	CA (HEI)	CA (LEI)	CSRA (organic)
Details	Primary & secondary tillage practices (e.g. plough, disc and tine) with simple crop rotation, and livestock external. High use of external inputs.	A significant reduction in tillage practices such as ploughing. Practices like strip tillage, or rip-on-the row are typical of reduced tillage.	Direct seeding equipment using tines. Production system lacks adequate soil cover and sound crop rotations. High use of external inputs.	Direct seeding equipment using discs. Production system lacks adequate soil cover and sound crop rotations. High use of external inputs.	NT or ZT using high quantities of external artificial inputs such as fertiliser, herbicides, pesticides. Production system has adequate soil cover and sound crop rotations.	NT or ZT using low quantities of external artificial inputs such as fertiliser, herbicides, pesticides. Production system has adequate soil cover and sound crop rotations.	ZT using no external artificial inputs such as fertiliser, herbicides, pesticides. Production system has adequate soil cover and sound crop rotations.
Qualifies as CSRA through livestock integration	NO				YES		
Sustainability level							

Source: Adapted from Blignaut et al. (2015)

Before considering a clear definition of CSRA, it is generally understood as a framework consisting of principles that centre around going ‘beyond sustainability’ to rejuvenate landscapes and farms through enhancing ecosystem processes such as water, nutrient and carbon cycles, practices such as minimising soil disturbance, integrating livestock, maximising soil cover, rotational grazing and outcomes such as improved soil health, biodiversity, climate resilience, ecosystem function and socioeconomic revival (Newton et al. 2020).

Following from Jayasinghe et al. (2023) and Lal (2020), we positioned CSRA as a transdisciplinary systems approach, which is a perspective supported by research and case studies mentioned in this report. We propose extending the definition to recognise the importance of integrating the knowledge of local landholders and indigenous people with established scientific knowledge. As such, we proposed the following definition:

CSRA is a principle-based agricultural and transdisciplinary systems approach that integrates local and indigenous knowledge of landscapes, as well as their management, with established scientific knowledge. It combines a range of adoptable principles with context-specific practices, focusing on soil conservation as the initial step to restore soil health, enhance ecosystem functions, building climate-resilient systems, and create improved socioeconomic conditions.

0.3 Key principles of CSRA

0.3.1 Origin and application of CSRA principles

As mentioned above, CSRA is applied in various combinations and systems that have the same goal of making the agricultural sector more sustainable and resilient, namely (see Annexure 1 for a description of these different systems):

- Regenerative agriculture (RA)
- Climate smart agriculture (CSA)
- Agroecology
- Conservation agriculture (CA)
- Organic agriculture
- Agroforestry
- Permaculture
- Biodynamic

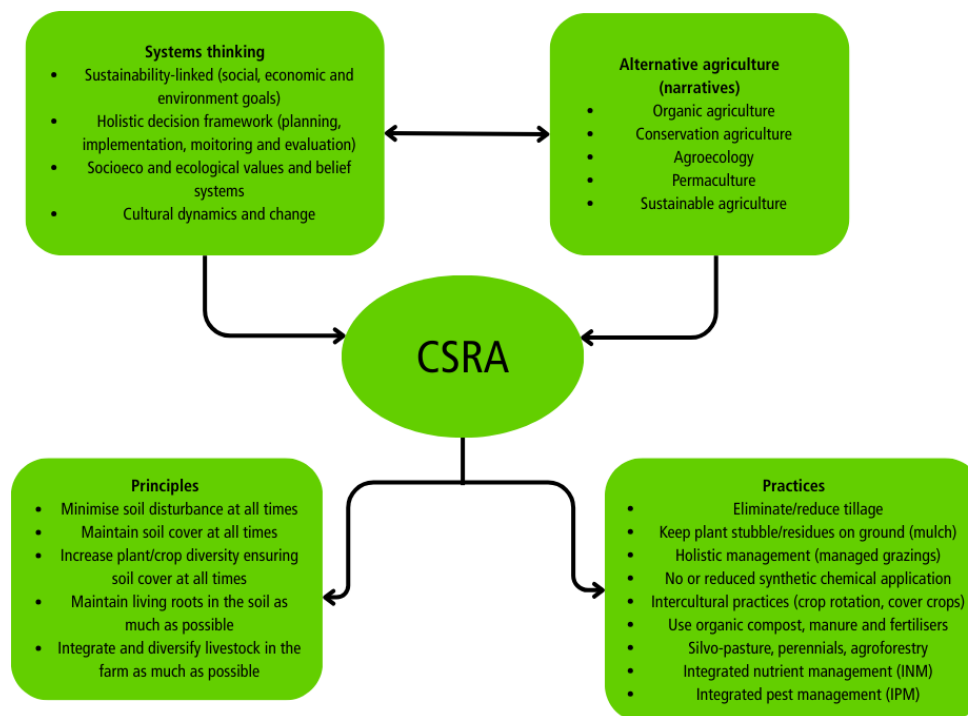


Figure 0.1 Key systems, principles and practices through which CSRA has emerged

Source: Adapted from Rai et al. (2025)

0.3.2 Requirements and intrinsic characteristics of CSRA principles

Integrating different principles into context sensitive agricultural systems serves to go 'beyond sustainability' and should meet the following requirements and intrinsic characteristics:

- They are universally applicable to all agricultural landscapes and land uses with locally adapted practices.
- They counter the destruction of rural livelihoods, loss of topsoil and increased water pollution caused by industrial farming practices.
- They enhance biodiversity and natural biological processes above and below the ground surface.
- They rejuvenate landscapes and farms through enhancing ecosystem processes such as water, nutrient and carbon cycles.
- They reduce mechanical and chemical soil disturbance to an absolute minimum.
- They build soil structure, improving soil health, recycling nutrients and ensuring local sourcing.
- They contribute to sustaining and improving functional diversity (both on a spatial and a temporal scale).
- They help to reduce and manage the use of external inputs such as agrochemicals and plant nutrients of mineral or organic origin in ways and quantities that do not interfere with, or disrupt, the biological processes.
- They facilitate good agronomy, such as timely operations, and improves overall land husbandry for rainfed and irrigated production.
- They are complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc.
- They serve as a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.

For CSRA they should fulfil the following requirements to be really “climate smart”:

- Overall emission reduction (fuel use, emissions from soil through carbon dioxide, methane and nitrous oxide) throughout the system and production chain.
- They assist with conserving and using water efficiently.
- Maximum use of the soil resource as a carbon sink to sequester carbon from the atmosphere, and as a “soil carbon sponge” storing the maximum amount of water.
- Climate resilient, making crop production more tolerant against drought, flood, hot or cold spells.
- Productive, so that it can sustainably feed the people without need to expand to new lands.
- It is profitable to lift farmers off poverty and reduce vulnerability in case of extreme events.

0.3.3 Description of CSRA principles

This section is a summary of all the principles that fall under CSRA and which are supported by empirical data from farms and research studies displaying a wide range of management practices to ensure the implemented principles are achieving CSRA goals and outcomes. According to Lal (2020), CSRA is all inclusive, and its site-specific package(s) must be finetuned in the context of biophysical factors and the human dimensions. Furthermore, **CSRA is an approach and process, not a recipe, that combines ongoing learning processes, continuous adaptation and the application of several principles.** These principles are summarised below (detailed descriptions are seen in Annexure 2):

1. Minimum mechanical soil disturbance through no/minimum till.
2. Keeping the soil covered for as long as possible through mulching, cover crops, grain residues, etc.
3. The introduction and promotion of (bio)diversity in the system through crop rotation, mixed cropping and cover cropping, among others.
4. The maintenance of a living root in the soil by the lengthening of the growth cycle through especially cover crops.
5. Minimum chemical disruption of the soil organic processes through integrated pest and nutrient management.
6. The introduction of livestock in especially crop production systems by allowing the grazing of cover crops, among others.

The multi-faceted benefits of CSRA as a climate change adaptation and mitigation measure are linked to the enhanced soil quality, the drawdown of atmospheric carbon, the development and enhancement of system-wide resilience and productivity as well as improved water retention capacity. Correctly applied principles and practices as shown in Figure 0.2 are the core of CSRA – it can be complemented and combined with other approaches to farming, such as organic farming, agroforestry, permaculture, etc.

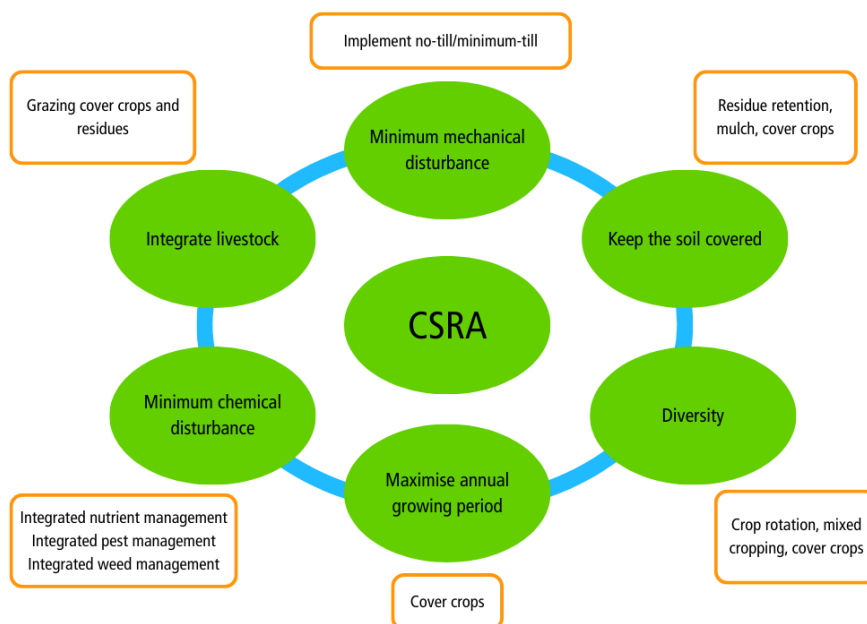


Figure 0.2 CSRA principles (in green) and practices (in orange)

0.3.4 High-level CSRA processes and outcomes

Core desired outcome – soil health

According to Schreefel et al. (2024), most research studies and publications done on CSRA shows that soil is the core of it and is fundamental to all CSRA principles and practices. In this respect CSRA uses soil conservation and restoration as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production.

Soil health is the over-arching theme for all the CSRA systems. For the past 150 years, the world has lost 30–75% of carbon in its prime agricultural soils, leading to a decrease in productivity of potential land and decrease in profitability. Reports show that around 30% of the world's croplands have been abandoned in the past 40 years due to soil decline (Jones 2018). In South Africa 46% of soil organic carbon in arable soils has been lost due to tillage (Swanepoel 2018).

There is consensus that industrialised agriculture is reducing the natural resource base. As a result, novel sustainable agricultural approaches and practices need to be adopted and applied at all scales of agricultural production to address the challenge of long-term food and nutrition security. The reduction in soil health affects human health due to a reduction in nutrients, minerals and trace elements. The quote “[t]here can be no life without soil and no soil without life, they have evolved together” is fundamental to all these agricultural ecological systems (Kellogg 1938 in Jones 2018).

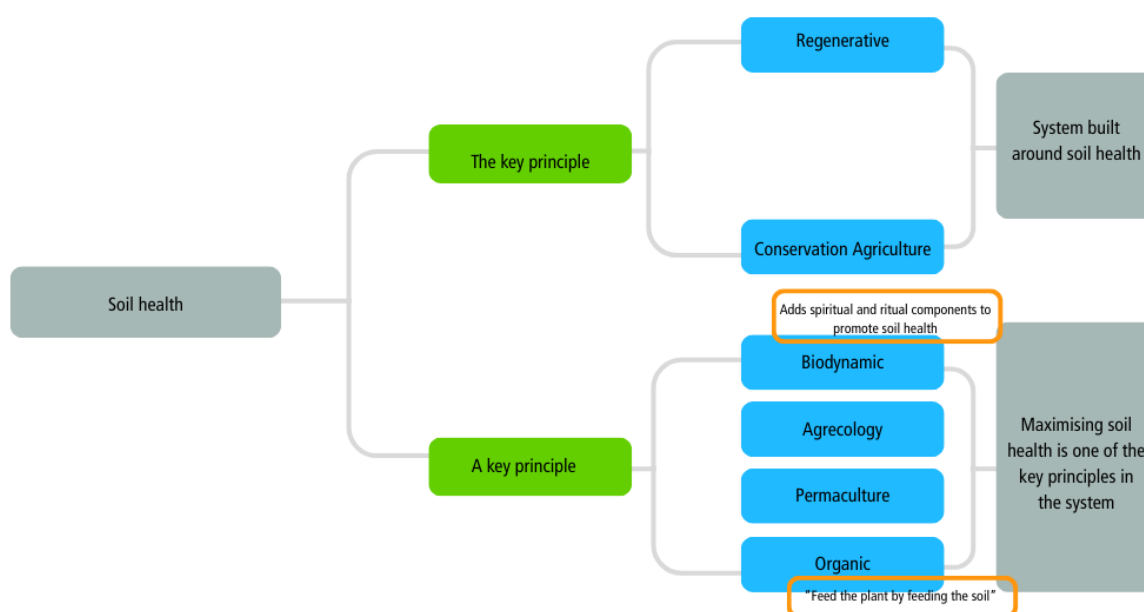


Figure 0.3 Soil health

Source: Own analysis based on Annexure 3A

CSRA benefits to major ecosystem processes

When CSRA principles are applied effectively, they positively impact four crucial ecosystem processes:

1. **Energy flow:** Regenerative agriculture captures solar energy through photosynthesis, converting it into biomass that nourishes the soil ecosystem.
2. **Water cycle:** By improving water infiltration and retention through soil organic matter and diverse plant cover, regenerative practices help replenish aquifers, restore waterways and mitigate the devastating impact of droughts.
3. **Mineral cycle:** Nutrient cycling is enhanced through the integration of cover crops, crop rotations and livestock grazing patterns. This reduces reliance on synthetic fertilisers while promoting efficient nutrient use.
4. **Diversity:** The interplay between diverse plants, animals, insects and microorganisms fosters ecological balance, creating vibrant ecosystems that are less susceptible to disease outbreaks.

Through adherence to and adoption of these principles and processes in CSRA, farmers play a vital role in healing the earth while cultivating nourishing food for our communities.

High-level CSRA benefits and outcomes

Various high-level outcomes (benefits) of CSRA have been identified and measured across multiple studies and contexts globally (Rai et al. 2025). These outcomes are achieved through the successful implementation of CSRA principles and practices (see Figure 0.4). They are unpacked and described in greater detail under each chapter (agricultural industries or sub-sectors) and various case studies included.

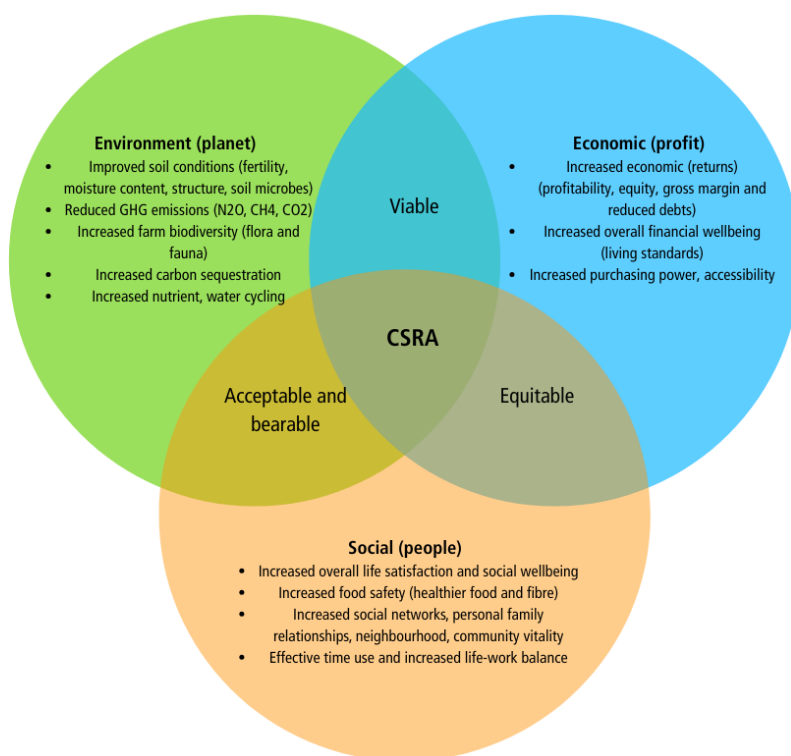


Figure 0.4 *Benefits and outcomes of regenerative agriculture*

Source: Adapted from Rai et al. (2025)



Part A

GRAIN PRODUCTION IN SOUTH AFRICA

Chapter 1 An overview of grain crop production in South Africa

Nobody is qualified to become a statesman who is entirely ignorant of the problem of wheat.

Socrates

1.1 Introduction

The Republic of South Africa (RSA) has an estimate of approximately 40 000 commercial farms, covering almost 40% of the total land area of the country (Stats SA 2020). Field crops make up 29% of the gross value of R435 billion of these commercial ventures (Stats SA 2024). However, this does not tell the full story.

The assumption that there are 40 122 commercial farming ventures in South Africa is based on the 2017 census of commercial agriculture (Stats SA 2020), which only counted farmers that are registered for VAT. This means the farm needed to have an annual turnover of R1 million. While this is a lot of money, it is still considered as a micro- or small-scale enterprise. Only 2 600 farms have an annual turnover of more than R22.5 million per annum (Sihlobo 2022). These farms are responsible for 67% of all farming income and generate more than 50% of the agricultural labour jobs in South Africa.

When the topic of agriculture and how it affects/is affected by climate change are discussed, the livestock sector is often seen as the main culprit and, hence, the most important sector where positive change must be implemented. However, the importance of grain crop production should not be underestimated, as grain crops account for a third of the consumed calories in the human diet (Soto-Gómez & Pérez-Rodríguez 2020) and indeed grain crop production often feeds into livestock production.

Approximately 100 million hectares, or about 80%, of South Africa is agricultural land (Environmental Affairs 2016, see also Figure 1.1). However, only 14% thereof has suitable soils and topography, and receives sufficient rainfall for arable crop production. The remainder is split between grazing, forestry and conservation. The farming sector in the RSA consists of approximately 40 000 commercial farms (Stats SA 2020) and between two and three million smallholder/subsistence farmers (Johnston et al. 2024). The smallholder farmers still contribute to the commercial sector, as any goods that are not used by the producers are sold/traded. Of the 40 000 commercial farms, 21.3% are field-crop farms, and 31.1% are mixed farms (Stats SA 2020). Thus, around half of the country's commercial ventures are involved in field crop production to a varying extent – although only a very small proportion of them are large-scale producers, as mentioned above.

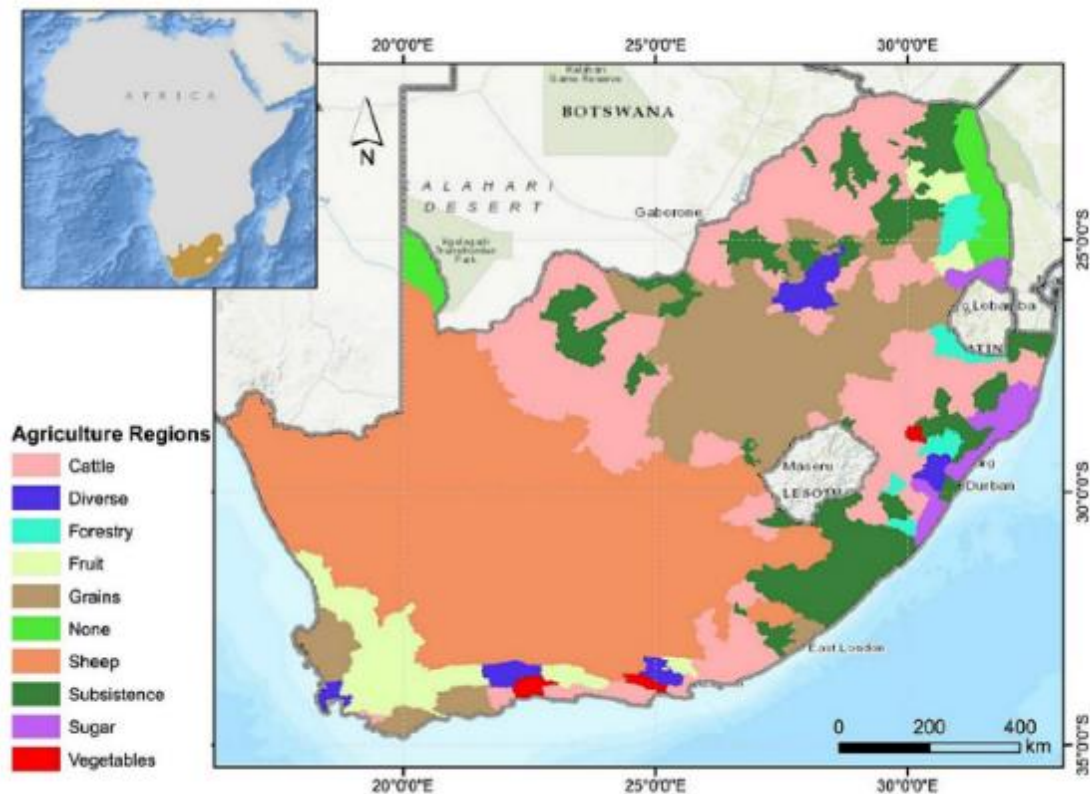


Figure 1.1 Grain crop production as part of various other agricultural industries across South Africa based on climatologically suitable areas

Source: Johnston et al. (2024)

Grain crops are split into two categories, based on season (summer grain and winter grain). Summer grains are the group of grains that are planted in the spring (Oct–Dec) and typically harvested in the fall/winter seasons (Apr–Aug). Summer grains include:

- Maize (corn) – white and yellow
- Grain sorghum
- Sunflower (oilseed)
- Soybean (oilseed)

Winter crops are planted in the fall (Apr–Jul) and are typically harvested in the spring/early in the summer (Oct–Dec). The following are winter crops:

- Wheat
- Barley
- Canola (oilseed)

More detailed definitions and classifications of the grain crops that is included in this report are listed in Table A4.1 in Annexure 4.

The grain crop industry in South Africa has grown considerably over the last two decades. Summer grain production went up from 8.8 million tonnes (2000/2001) to 19.7 million tonnes (2022/2023) (Stats SA 2024), on a total area planted that hardly changed. While the area planted with winter crops decreased, the total production increased. The growth and decline in these numbers are shown in

Figures 1.2 and 1.3. The increase in yield is attributed to improvements in genetics and farming practices (BFAP 2024).

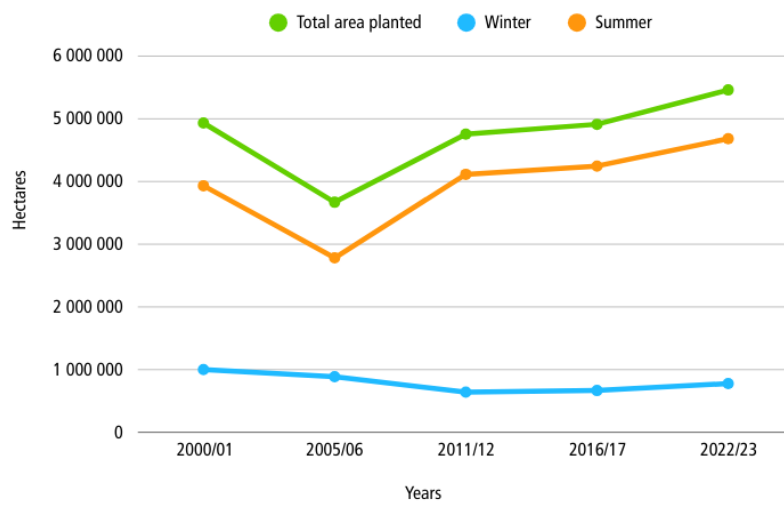


Figure 1.2 *Change in area planted with summer and winter crops*
Source: Stats SA (2024)

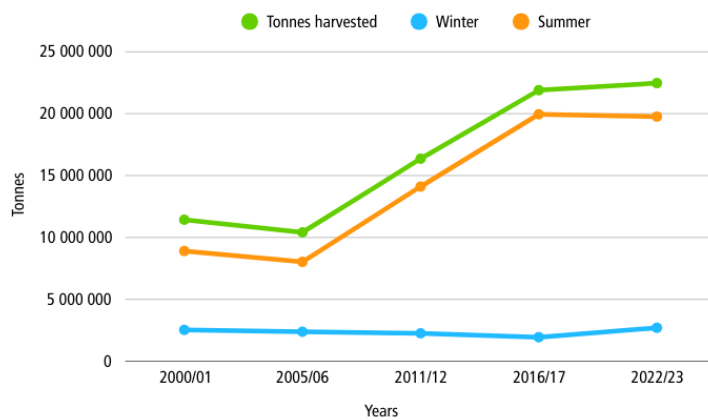


Figure 1.3 *Change in tonnes harvested*
Source: Stats SA (2024)

1.1.1 Economic importance

The total income earned in the agriculture and related services industry in 2023 was R494.7 billion, a 9.9% increase from 2022 (Stats SA 2023). Figure 1.4 shows a sector-by-sector breakdown, for agriculture specifically.

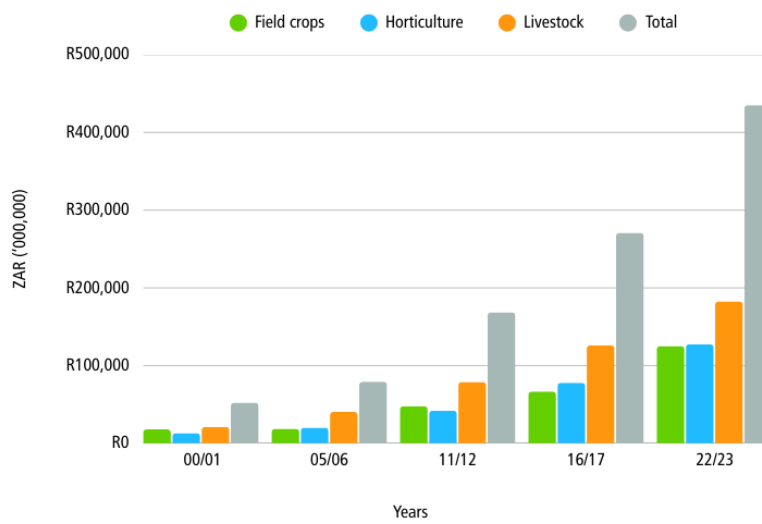


Figure 1.4 The gross value of agricultural production

Source: DALLRD (2024)

The gross value of the field crop sector in South Africa shows a steady increase over time, growing from R60 billion in 2017/8 to R125 billion in 2022/23 (DALLRD 2024). This is a contribution of 28.7% to the total gross value of the agricultural sector in South Africa in the 2022/23 year. Figure 1.5 shows the percentage contribution of the field crop sector to the value of the entire agricultural sector over the last 25 years.

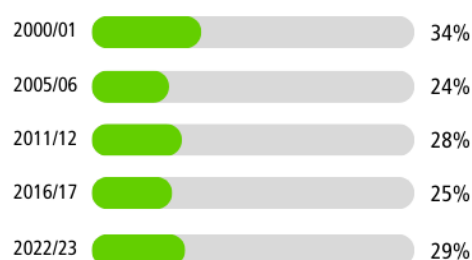


Figure 1.5 The contribution of the field crop sector to the national agricultural sector

Source: DALLRD (2024)

Grain crops make up R113.5 billion (22.9%) of the income that is generated by these ventures. In terms of percentage contribution, this is the same as the contribution of the field crop sector in 2017. However, the monetary value of that 23% has grown from R69 billion (Stats SA 2020) to the mentioned R113.5 billion – indicating a 60.7% growth in the value of the sector over the six-year period between 2017 and 2023. Comparing this to the growth of the entire agricultural sector of 67.3% (R332.8 billion to R494.8 billion) over that same period, the growth of the field crop sector is lagging slightly, but still healthy. For the year that ended in December 2021, the agricultural sector contributed 2.7% to the national Value Added Tax (DALLRD 2024), showing neither growth nor decline, as shown in Figure 1.6. Figure 1.7 shows the change and trends in the gross and net income of the agricultural sector in RSA.

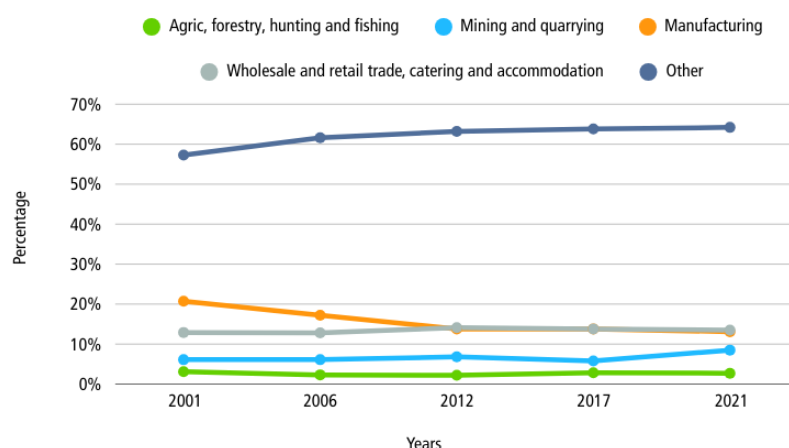


Figure 1.6 % VAT contribution of different sectors

Source: DALLRD (2024)

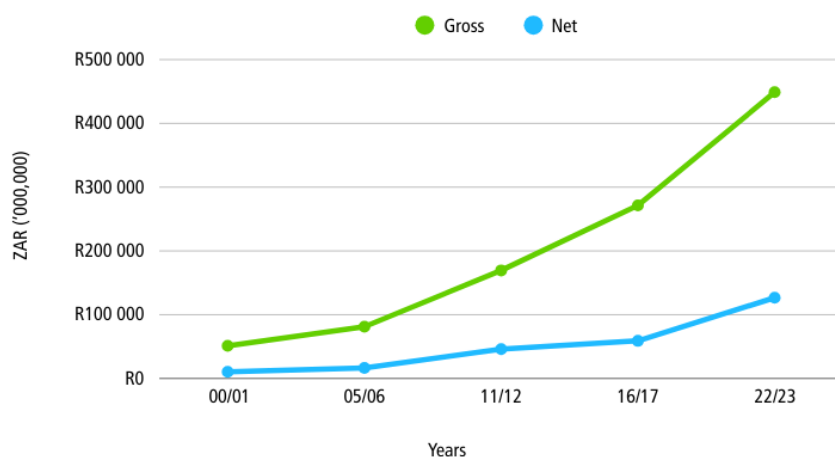


Figure 1.7 The gross and net income in the agriculture sector
Source: DALLRD (2024)

Figure 1.8 shows how the price index of grain crops has changed over the last three decades. The consumer price index was tracked, the grain crop index as well as single crop indices. The value of each product in 2015 was taken as 100, and the other values interpreted accordingly.

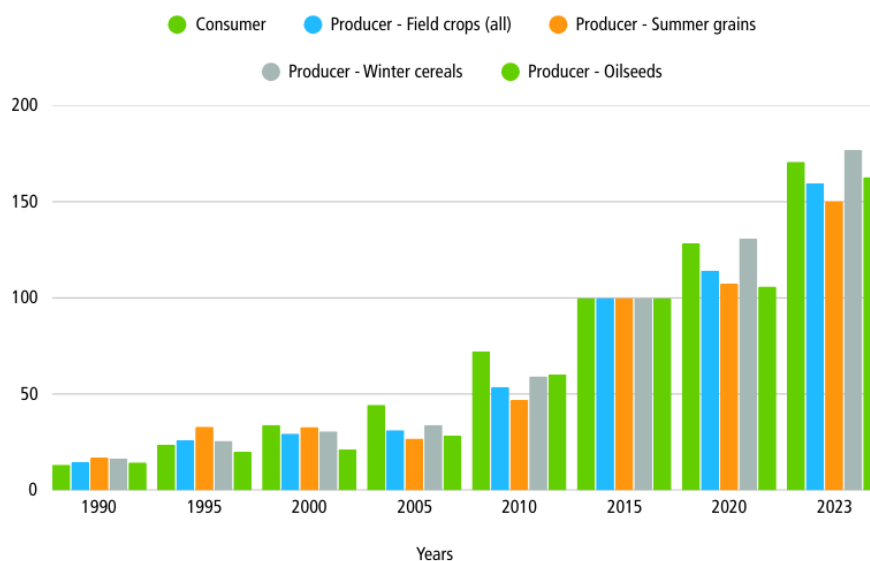


Figure 1.8 Increase in producer price over time
Source: DALLRD 2024

The producer and consumer prices mostly stay closely correlated, except for 2000–2010 where the consumer price was much higher. There has since been a slight correction in the pricing; however, it is only the production of winter cereals that has grown at a slightly higher rate than the consumer

price. In all other metrics the producer price lags, meaning that there is increasing pressure on farmers to produce more to make the same percentage of profit – as input prices will follow similar trends.

1.1.2 Employment

South Africa has a population of just over 63 million people, of whom 16.9 million are employed (Stats SA 2024), 924 000 in the agricultural sector. Over time the employment of the agricultural sector as compared to the total employment figures has remained at between 5% and 6%.

Of this number, the grain crop industry employs approximately 16% of the total agricultural workforce (Stats SA 2020). Up to 44% of these workers are seasonal workers, while the rest is skilled labour/working proprietors (Stats SA 2022).

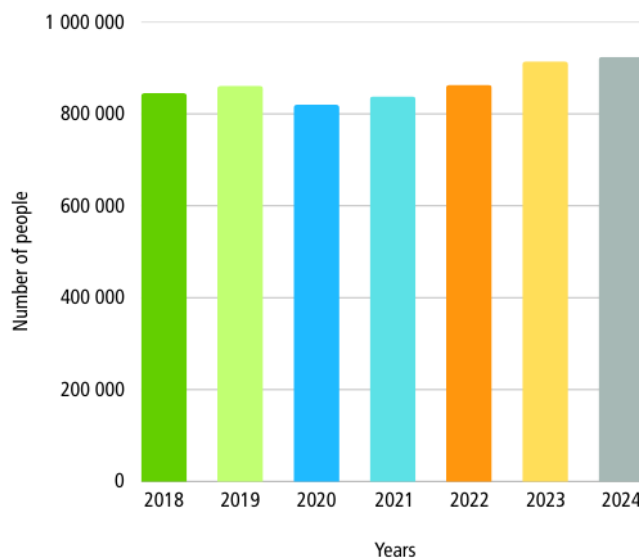


Figure 1.9 *Number of people employed in the agricultural sector*

Source: Stats SA (2024)

1.1.3 Imports and exports

Regarding exports, by far the largest commodity of the South African agriculture sector is maize. When compared to the total value of grain exports (excluding oilseeds), it has contributed more than 70% over the last 20 years. Figures 1.10 to 1.13 show the value of grain exports and imports, respectively (Trade Map 2025). More detail on the import and export market is provided in Annexure 4 section A4.4.

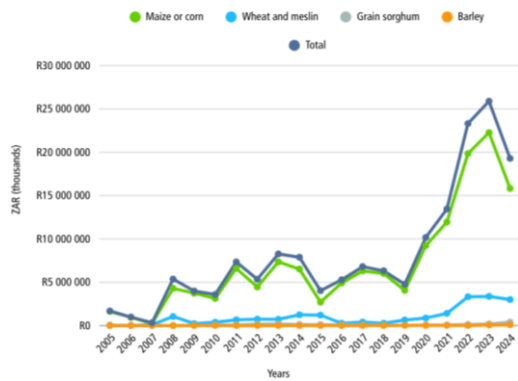


Figure 1.10 Value of exported grain

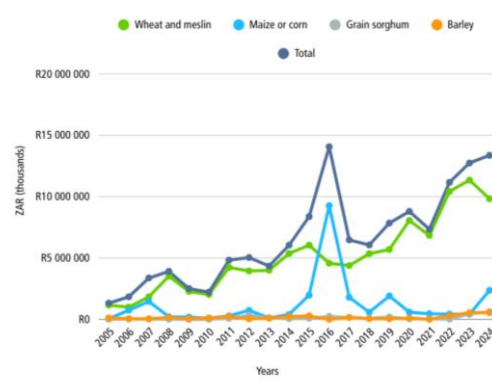


Figure 1.11 Value of imported grain

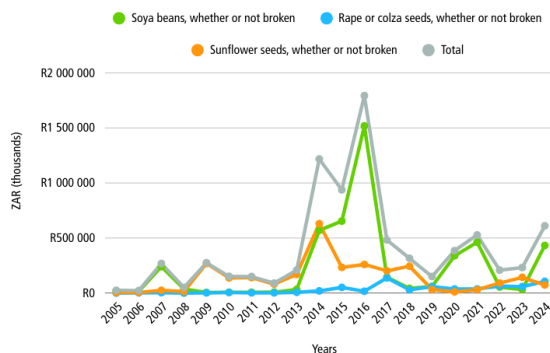


Figure 1.12 Value of exported oilseeds
Source: Trade Map (2025)

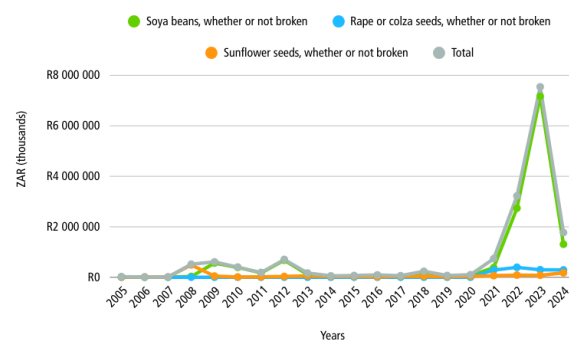


Figure 1.13 Value of imported oilseeds

1.2 Challenges faced in the grain farming industry

Presumably, when comparing the growth of the commercial grain crop production sector in RSA to that of the national agricultural sector, it would seem like the commercial grain crop production sector is doing well. However, it has become clear that the sustainability of the grain industry is under pressure and it requires changes that would ensure its growth.

The threats to future growth are quite wide-ranging and below is a list that attempts to provide an overview of some of the problems faced.

- Current farming practices**
 Deep-tillage monocrop systems lead to environmental degradation which affects a farm's resilience, sustainability and profitability (Maluleke et al. 2024) resulting in high reliance on external inputs as well as acceleration of the degradation cycle.
- Rising fertiliser cost**
 Yields on farms and soils that have been farmed intensively for several years will drop over time. To protect and sustain their yields and income, farmers have started to use increasing amounts of chemical fertilisers. That is in and of itself an issue that must be addressed, but furthermore the cost of said fertilisers is increasing year-on-year (see Figure 1.14), which places ever greater financial burdens and risks on the farmers themselves.

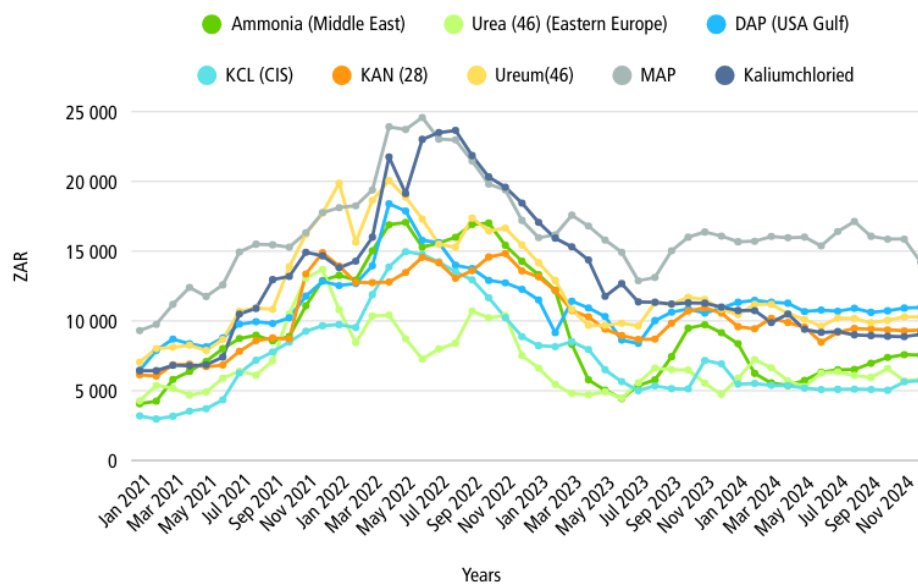


Figure 1.14 Fertiliser prices, 2021–2024

Source: GrainSA (2025)

- **The growing effect of climate change**
 - Decreased/less predictable rainfall: There is a decrease in annual rainfall, as well as when/how it does rain.
 - More extreme weather events: South Africa will start experiencing more heatwaves and more droughts (Calzadilla et al. 2014).
 - The increasing average temperature.
- **The damage done over time by tillage**
 - Average soil loss from water erosion under annual grain crops of 13t/ha/y (Le Roux et al. 2008).
 - Ploughing resulting in gradual soil erosion as well as reducing the soil organic carbon (SOC).

The threats and challenges listed here include some that will only increase in severity over time. As farmers keep pursuing ever greater yields, more and more fertiliser and pesticides will be used. This will worsen the possible environmental problems, soil quality will further degrade, and the cost of production will continue to increase. An alternative approach must be followed.

1.3 The key role players contributing to growing CSRA

There is a well-known proverb that states that “it takes a village to raise a child”, which is certainly true in the case of CSRA. No one person, institution or organisation could keep these wheels turning – they are too many, and too varied.

Table 1.1 is a short summary of the key role players from the government, education and private sectors. A more comprehensive list and analysis are included in Annexure 7, section A7.1, which is where the information in Table 1.1 is sourced from.

Table 1.1 *A shortlist of key role players in the grain industry*

Government bodies	Industry bodies	Organised agriculture	Research entities	Other
DoA NAMC Provincial and municipal DoAs	SAGL AgBiz Industry Trusts	Producer cooperations AgriSA GrainSA SAGRA	Agricultural Research Council ASSET Research Various universities	Various seed companies Equipment suppliers Fertiliser and chemical suppliers

Source: Network analysis done in Chapter 10 and Annexure 7

Chapter 2 Climate smart regenerative grain crop production: Evidence from the field

2.1 Adoption of climate smart regenerative agriculture

The concept of CSRA as it has been described in Chapter 0 is not new. The origins of climate smart practices in RSA go back to 1980 (Smith 2021). Having said that, as the severity of climate change becomes all the clearer to us, the adoption and “popularity” of CSRA is growing fast. One only needs to look at the global estimates for CA cropland. In 2008/9 the estimate was that this constituted approximately 7.5% of global cropland. The figures for 2013/14 (11%) and 2015/16 (12.5%) indicate rapid growth of CA cropland, as well as an increasing adoption rate (Kassam et al. 2018). Extrapolating the adoption data of the last census from 2018/19 we should now have about 250–270 million hectares of annual cropland under CA, which is nearly 20% of the global cropland, with an additional growing area of orchards and plantation crops also adopting CA (Inauguration Keynote held by Theodore Friedrich at the 9WCCA in Cape Town, South Africa, July 2024). These figures place South Africa twelfth out of all the countries listed in terms of hectares under CA cropland. It is important to note that the metric is hectares and some of the countries listed (e.g. USA, Brazil, Canada and China) are considerably larger than South Africa. Therefore, when percentage adoption is considered, the rankings will change.

Having considered the grain sector in RSA, as well as the principles and benefits of climate smart regenerative agriculture, the so called “subsector” of practitioners that have adopted climate smart principles need to be investigated. It is important to note that of the six principles mentioned in Chapter 0, adopting the three CA principles (minimum soil disturbance, organic soil cover and crop rotation) qualifies the practitioner to be included in this bracket.

2.1.1 Commercial farming

Smith (2021) published a report on the adoption of CA in South Africa, giving a detailed overview of the percentage of CA adoption per magisterial district. The definition used for CA was (Smith 2021:8):

No-till planting (either disc or tine No till planter) + crop residues (>30% soil cover) + at least 2 crops or more in rotation (strip till or any other tillage does not qualify).

Smith (2021) found that of the total area under commercial annual crop-livestock systems, CA is practiced on 25% thereof. This increased from 23% in 2015. It is important to note here that the definition of CA used above falls under the umbrella of CSRA defined in Chapter 0. Going by the stages of CSRA in Table 0.1, it includes all farmers who fall into stages 5–7, both CA and RA. This allows for the inclusion of farms and farmers that are in the final transition phase, as well as those who have completed the transition.

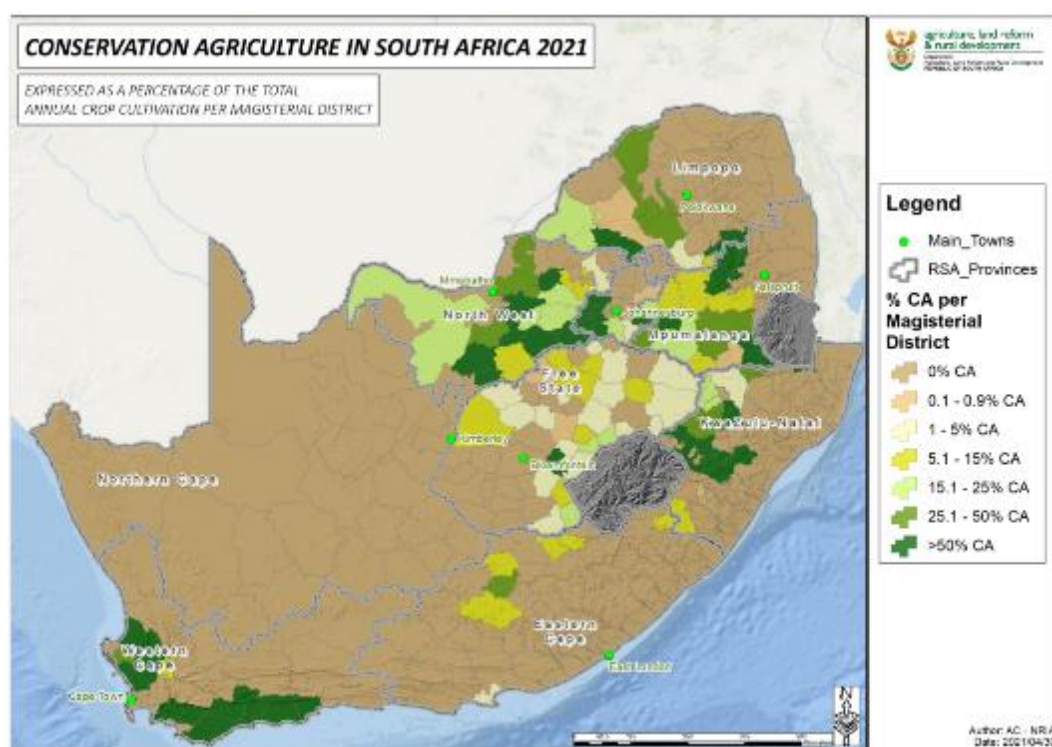


Figure 2.1 Adoption percentages of CA

Source: Smith (2021)

As a part of the survey for which the results are presented in Figure 2.1, the provincial adoption rates of CA were also recorded. These rates are shown in Table 2.1, and it shows that the three leading provinces in South Africa are (in order) 1) Western Cape, 2) KwaZulu-Natal and 3) North West. The most interesting point to note is the low adoption rate in the Free State, which by all accounts is the breadbasket of South Africa. The Free State province has the largest area under annual crop-livestock systems, which as can be seen in Figure A4.1 is dominated by maize production.

Table 2.1 The percentage adoption of CA

PROVINCE	Total annual crop area (ha)	Area under CA in 2021 (ha)	Area under CA in 2015 (ha)	CA adoption in 2021 (%)	CA adoption in 2015 (%)
Western Cape	1 569 277	804 866	564 940	51%	36%
North West	890 437	330 464	142 470	37%	16%
Mpumalanga	850 484	205 598	314 679	24%	37%
Free State	2 196 986	73 520	175 759	3%	8%
KwaZulu-Natal	164 620	62 956	82 310	38%	50%
Limpopo	255 866	68 834	63 967	27%	25%
Gauteng	173 435	57 649	116 202	33%	67%
Eastern Cape	160 307	3 194	0	2%	0%
Northern Cape	69 498	0	7 645	0%	11%
TOTAL	6 330 910	1 607 081	1 467 971	25%	23%

Source: Smith (2021)

2.1.2 Smallholder and semi-commercial farming

While the adoption of CA in the commercial sector has been discussed, there is a large smallholder and semi-commercial farming community in RSA as discussed in Section 1.1, consisting of between two and three million smallholder/subsistence farmers (Johnston et al. 2024). Most of these farmers are practicing a mixed system, consisting of grains and livestock.

In a review of the effect of CA on smallholder farms, Mango et al. (2017) concluded that even on a small scale there are large benefits to be had, if CA is implemented and managed correctly.

Regarding the adoption across RSA, it varies. In a review of CA practices among smallholder farmers in the Eastern Cape province, it was found that only 22% of the farmers practice the first three CA principles which are NT, residue retention and crop rotation (Muzangwa et al. 2017). This is similar to what Mango et al. (2017) found. They studied CA adoption in Zimbabwe, Mozambique and Malawi and found that 19.8% of smallholder farmers practice CA principles. While this data does not provide the full picture, it does show that the adoption rate of CSRA principles among the smaller farmers is not what was expected.

2.2 Grains and cereals in other branches of agriculture

It is mentioned above that grains account for a third of consumed calories (Soto-Gómez & Pérez-Rodríguez 2022). While a large percentage of grain crops are grown for human consumption, much of it is used in different parts of the agricultural sector, or even in industry.

In the livestock industry, maize, sorghum, soybeans and barley are the major feed grains used. The aim thereof is to use the high starch content (and therefore energy density) in the ruminants' diet to support growth and therefore meat production. The above crops can also easily be turned into silage.

Corn can be turned into fuel ethanol, and additionally corn and other grains are turned into many food and industrial products such as starch, sweeteners, corn oil, etc.

2.2.1 Horticulture

Two of the CSRA principles previously mentioned in Chapter 0 (diversification of crop species as well as permanent organic soil cover) can be implemented through the integration of vegetables. Legumes (e.g. chickpeas or cowpeas) are "nitrogen fixers", meaning that instead of using soil nitrogen, they deposit atmospheric nitrogen into the soil – which grains can benefit from. Hence, legumes are often used as a cover crop, or in intercropping (Chamkhi et al. 2022). Intercropping is when two (or more) crops are grown in the same field simultaneously. This can either be completely mixed, in distinct rows/sections or in a relay form, where the second crop is planted after the first is well established. The second is then either planted between the rows of the first crop or sown by hand on the field.

The "intercrop" in this case often consists of root vegetables (e.g. radishes) and beans or cowpeas – if the main crops consist of maize. Squash or potatoes are also options to consider (Grain SA 2018).

The practice of intercropping has the following potential benefits:

- The build-up of SOM, as there is more organic matter on the field every planting season.
- Root vegetables help break up the soil and assist in water and nutrient infiltration.
- Legumes make more soil nitrogen available.
- Once the crop dies the organic matter left behind forms part of a mulch layer on the soil.
- If livestock is integrated into this system, then there is more food available.

2.3 Case studies on the adoption of climate smart regenerative agriculture

Case study 1: Michael Mandy, Harrismith, Free State



Figure 2.2 *How the maize fields looked in 2019, the year the Mandys fully adopted NT, interseeding and winter cover crops*



Figure 2.3 *Interseeding in 2024. Note the difference in ground cover and the cover crops planted in between the rows*

The Mandy family has been on their farm in the eastern Free State just outside Harrismith for six generations, focusing on cattle and crops for feed.

They used to have massive dust clouds during the winter, resulting in the small maize and soya plants getting sandblasted early in the planting season. Water runoff from the fields was a big problem, as was the soil erosion that resulted from that.

Driven by a need for positive change where the fertile topsoil is not blowing and water running away, the Mandys started experimenting with cover crops in 2017. This was followed by changing over to less tillage and focusing on building organic soil cover on our lands. After two years of experimenting, they made a large change to their practices in 2019: converted to NT, fully adopted interseeding as well as incorporating a winter cover crop. The way they used the fields as grazing for the cattle also changed to higher density strip grazing.

Motivation was to see change. They were not happy with the old system and wanted to do things differently. They set small goals and achieved those quickly and have been building on those until now.

As with any farm, there was a transition period. After starting the shift to CSRA in 2017 and adopting interseeding in 2019, they feel they only had the system correct by 2022. The same goes for strip grazing cattle on the maize stalks, it took them about two winters to get it right. The implementation of winter cover crops also took time, partly because they had to slowly buy bigger planters to be able to implement it the way that they wanted to.

The results, however, are clear. Soil erosion has been halted, and rainwater can actually penetrate the soil and be absorbed into the water table. The only runoff that they see now is when the water table is full, and then it is clean water – as opposed to the muddy water that carries a lot of topsoil with it. The water quality in their dams has also increased as a result of this, with the dams full of clean water whereas previously there was a lot of soil suspended in the dams. Before changing to CSRA, winters were tough for the cattle in terms of available grazing, and now they almost have more food in winter than summer for cattle. There has also been a large uptick in soil activity, birdlife and wildlife. All of the above, while their crops are getting healthier year by year. As a result, their yields are climbing, unlocking more profit per hectare than before.

Their advice to farmers that want to move to CSRA: “start with what you are comfortable to do. Ask and learn from other farmers who have made mistakes before and can help teach you. Push the boundaries hard on a small piece to see where the line is. Remember everyone farms differently but we all got a few similar goals in mind. Build a system that works for you. Doesn’t necessarily have to work for the neighbour but as long as your system does what you want it to do. Remember the more pedals and steering wheels in your system the more things you can control at the end of the day that may also lead to less risk in the future.”

(Personal communication with Michael Mandy)

When the discussion regarding CSRA, principles, challenges and implementation starts, one’s mind immediately goes to large, commercial ventures. It is stated in Section 1.1 that there are ~40 000 commercial farmers in South Africa, of which only ~2 600 generate the majority of income. Much has been said and written about CSRA implementation on ventures of this scale. However, what about the effect that CSRA can have on smallholder farms? As also stated, South Africa has between two and three million smallholder/subsistence farmers (Johnston et al. 2024).

The following case study was done on one such a farm, in Ezibomvini, a small village near Bergville in KwaZulu-Natal.

Case study 2: Phumelele Thembisile Hlongwane, Ezibomvini, KwaZulu Natal

Whereas commercial ventures focus on income, for Phumelele that is secondary to providing food for her family. She plants a plot of vegetables for in-home use as well as some field crops. For both of the above, she only sells what their household doesn’t use. Phumelele joined the CA Farmer Innovation Programme that was run under ASSET Research, funded by The Maize Trust and implemented by Mahlathini Development Foundation (MDF) (<https://mahlathini.org/>) in smallholder communities, and after two years of practicing CSRA with the help of that programme they structured two different trials on her homestead. The first was a crop yield trial that consisted of a control crop of maize, and various combinations of intercropping/relay cropping or crop rotation.

The trial results across two seasons show increases on the plots where intercropping was practiced, with the most significant increase being on the plot where a maize with a summer and winter cover

crop was followed by maize, intercropped with beans. The results from her plots (in terms of t/Ha) put her on-par or above the commercial yield in the area.

The second trial was a rainwater runoff trial. The rainwater runoff in both her maize plots (conventional and CSRA trial) was recorded over six rainfall events. They found that not only is the rainwater runoff of the CSRA plot much less than that of the conventional plot (11.7% vs 20.1% on average), the water that runs from the CSRA plot runs clean – much less sediment due to soil lost through erosion. Not only does this attest to the efficacy of CSRA to restore the infiltration and water-holding capacity of soils, it shows how quickly it can happen. Even without the suggested permanent organic soil cover in this case, runoff was halved in a period of only two to three years.

In Phumelele's case the benefits of CSRA is not "just" about the bottom line. As stated above, most of her crop goes towards household use, and only the excess is sold. Increased yields for her (while keeping the cost to a minimum) could lead to both cost savings (as less food has to be bought) and additional income, as there is more crops that can be sold.

Apart from being a member of the Farmer Innovation Programme, Phumelele is also a member of their local farmer support centre model. The idea behind the farmer support centre is to assist farmers in buying inputs at the scale they need, without it becoming expensive. The result of the centre is that more people in their community can afford to start planting again, whereas before that was not possible.

(Adapted from Ngcobo and Kruger 2021)

Clearly, the positive effect of following CSRA principles is not limited to large-scale operations, but CSRA is just as effective on smallholdings. However, there is another point that needs to be highlighted from this case study – the importance of both the programme that was initiated by MDF under the CA FIP, as well as the community farmer support centre. The education and support offered in terms of purchasing production inputs are invaluable, and sorely needed to get small farmers and communities going.

Case study 3: Izak Dreyer, Vrede, Free State

In the case of Goedgedacht farm, the transition from conventional agriculture to CSRA systems took eight years. The specific changes implemented were to plant cover crops in rotation, and to implement ultra-high-density grazing for their livestock.

The observed benefits in this case are legion, all of which have been discussed in previous sections of this report. To highlight a few:

- The reduced need for tillage has reduced the cost of working their fields drastically – this is both in terms of fuel consumption as well as maintenance. They recorded a reduction of kilowatts per hectare of to 40%.
- Increased water infiltration rate as well as decreased evaporation rates and soil temperatures.
- Nitrogen application rates have decreased by 40%.

- Weed suppression by the cover crops.
- Lower soil acidification, so a reduced need for liming.

Izak has started planting winter cover crops which further contribute to improving the overall condition of the soil, but also as additional feed for his cattle. They are only able to do this due to the increased soil moisture, unlocked through the implementation of CSRA practices.

In an on-farm research project to study soil health it was found that the soil food web (using beneficial nematodes as indicators) of the plots managed with CSRA principles was much healthier than in the reference sites. The CSRA site had a lower Carbon:Nitrogen ratio, indicating mature soils with high potential for energy flow and nitrogen availability.

In researching the effect of inorganic nitrogen on the abovementioned soil health, a direct negative correlation was observed. This suggests that high nitrogen-based fertiliser application rates contribute to “keeping” the soil degraded, as the energy flow and also the availability of the nitrogen that is present are also negatively influenced.

The results obtained from the study indicate, among other factors, that 1) over time the implementation of CSRA principles have a net positive impact on soil health, and that 2) external inputs such as herbicides and nitrogen application can be reduced drastically as the soil recovers. The reduction should be implemented piecemeal over time, but based on the on-farm observations Izak believes that apart from the 40% reduction that they have already done further reductions in nitrogen application rates are possible as soil health continues to increase.

(Adapted from du Preez et al. 2021)

Case study 4: George Steyn, Ottosdal, North West

A case study on the farm Humanskraal owned by George Steyn, demonstrates the restorative potential of conservation agriculture (CA) on severely degraded soils. Years of continuous tillage and water runoff had led to significant soil erosion, including sheet, rill and gully formations, resulting in diminished soil fertility and structure.

To address the degradation, the Grain SA/ASSET Research CA research team collaborated with Steyn to implement a biological soil rehabilitation strategy. This involved planting a diverse ten-species cover crop mix using an Amazon spreader for small seeds and a John Deere no-till planter for larger seeds. The mix included legumes, grasses and brassicas like radish, aiming to enhance soil biodiversity and structure.

The summer cover crops produced an average of 12 tons of dry matter per hectare. This biomass contained approximately 168 kg of nitrogen, 24 kg of phosphorus, and 249 kg of potassium per hectare. As the cover crops decomposed, these nutrients became available to subsequent crops, reducing the need for synthetic fertilisers.

Soil samples collected during the cover crop’s growth stage underwent Haney soil health analysis. Results indicated low levels of available nutrients and organic matter, reflecting the soil’s degraded

state. However, the introduction of cover crops began the process of rebuilding soil organic matter and microbial activity, essential components for long-term soil fertility.

Following the cover cropping phase, maize was planted with minimal fertiliser inputs: 33 kg/ha of nitrogen, 18 kg/ha of phosphorus and 12 kg/ha of potassium. The remaining nutrient requirements were met through the decomposition of cover crop residues. This approach led to a predicted maize yield of 7.5 tons per hectare, indicating successful soil restoration.

This case study illustrates that implementing conservation agriculture practices, particularly diverse cover cropping, can effectively restore degraded soils. By enhancing soil structure, increasing organic matter and promoting nutrient cycling, CA offers a sustainable pathway to rehabilitate soils and improve crop productivity.

(Adapted from Trytsman and Smith 2017)

The case studies above are evidence of the fact that CSRA is not only applicable to large-scale commercial operations but that it is also beneficial to smallholder/subsistence farmers. However, the cases above are 1) limited to South Africa so the practices may be limited to what is known locally and 2) don't quantify the nett cost/savings of first implementing, and then the results of, CSRA. The case below addresses both these points.

Cased study 5: Kurt Heward, Cassia County, Idaho

Heglar Creek Farms in Idaho selected 1 700 of their approximately 4 000 acres as a soil health case study. The farm grows crops like alfalfa hay, corn silage and triticale silage primarily to support a livestock operation. In recent years, the farm has undergone a shift in management practices to improve soil health, increase operational efficiency and boost profitability.

Kurt Heward implemented a suite of soil health practices centred around conservation crop rotation (CCR), cover cropping, no-till and reduced-till systems, and double cropping. This marked a departure from traditional methods that relied heavily on tillage and extended single-crop rotations. The revamped rotation includes three years of double-cropped corn and triticale, followed by one year of cover crops or four years of alfalfa.

Previously, fields were tilled in both fall and spring, which often depleted soil moisture. By switching to no-till and reduced tillage (for corn/triticale and alfalfa, respectively) and thereby minimising soil disturbance, the farm has improved water retention and soil structure. Additionally, the residue left by triticale provides a natural mulch, reducing erosion and supporting the subsequent no-till corn crop.

Kurt first experimented with cover crops in 2017 and now routinely incorporates diverse 6- to 12-way cover crop mixes, including legumes, brassicas and grasses. These are seeded after triticale harvests and occasionally grazed over winter. The covers not only boost soil biology—improving microbial diversity and organic matter—but also offer feed for livestock, making them multifunctional.

The introduction of triticale as a double crop after corn has proven highly successful. Triticale is inexpensive to grow, complements corn in rotation, adds diversity, provides winter soil cover and serves as quality forage for dairy cows. In three out of every four years, triticale is interseeded into alfalfa after the fourth cutting to increase yield in the following season—enhancing land productivity without expanding acreage.

A partial budgeting analysis showed that these practices have significantly improved the farm's bottom line. Despite the initial investment, the farm saw an annual per acre gain of \$156, emphasising the strong financial case for soil health practices. The net income on the 1 700-acre study area increased by \$156 per acre per year, translating to a total annual gain of \$265 264 and a remarkable 309% return on investment.

Their commitment to soil health has not only improved the physical and biological characteristics of the farm's soils – raising organic matter from 2% to nearly 3% in five years – but also enhanced farm profitability. They are now focused on long-term sustainability goals, including the possibility of eliminating synthetic fertilisers by leveraging biologically active soils.

(Adapted from Tillman 2024)

For additional case studies that provide evidence as to the efficacy of CSRA in grain crop production kindly refer to the below case studies listed in Chapter 5:

- Case study 1: Bertie Coetzee. This is a fully integrated crop-livestock system, where wheat and maize are planted following an organic no-till process.
- Case study 6: Danie Slabbert. This is also a fully integrated crop-livestock system. Cover crops are utilised for permanent organic soil cover, and crop rotation to increase soil quality.
- Case study 7: Danie Bester. Danie does a Soybean, maize and cover crop rotation, and has fully integrated cattle, sheep and chickens into his system.
- Case study 8: Magnus Theunissen. Magnus practices interseeding (similar to the Mandy farm mentioned above), and rotates his cash crops with cover crops which are then used for grazing as well.
- Case study 9: The Zunckel family. Crop rotation to increase soil quality.
- Case study 10: Agronomy department, University of Stellenbosch. This case study shows that combining no-till, crop rotation and livestock integration assists with controlling and reducing the weed load.

2.4 Training and extension strategy for farmer support and resilience on CSRA in the grain crop industry

Derpsch (n.d.) indicated that investment in public goods over a 10 year period, in the form of specialist training and extension programmes in CSRA, would increase the rate of adoption of these technologies and be an economically and environmentally attractive investment in a specific country. Similar to the CA Farmer Innovation Programme (CA FIP) implemented in the summer rainfall grain production regions of South Africa (see <https://assetresearch.org.za/conservation-agriculture/>) and various other successful CSRA initiatives around the world. Derpsch (n.d.) proposed that such a programme should facilitate farmer-led or -centred development and private sector extension initiatives. This could be

achieved by supporting self-organized groups of CSRA farmers (e.g. study or learning groups) either directly, or indirectly through the technical departments of farmer co-operatives or other suitable entities. From these experiences the proposed training, learning and awareness activities, in combination with substantially increased farm profits, are expected to provide sufficient incentives to encourage most cropping farmers to adopt integrated CSRA systems. These changes in farm production methods are expected to reverse the current trend of declining crop productivity and lead to an economically, ecologically and socially sustainable and resilient form of commercial cropping in a country or region. In South Africa, like in Paraguay and the rest of South America, no subsidies are paid to farmers. Either you do CSRA or you end up selling your farm to your neighbour, for economic and ecological reasons.

The following important principles underlay a farmer-centred systems approach:

- on-farm, within local farming contexts
- experiential and discovery learning
- continuous interaction and dialogue (participatory)
- facilitation and reflection on all levels
- co-learning, or learning-by-doing using farmers as key partners
- social learning in groups or innovation platforms

This systems approach aims to facilitate and support farmers to make transformational change, and to bridge the so-called investment- or J-curve, from traditional harmful conventional systems to CA/RA principles and practices. This transformation process requires critical attention to all the elements of the 360-degree solution (see Figure 2.4), such as human capacity, infrastructure development, capital investments and institutional support.

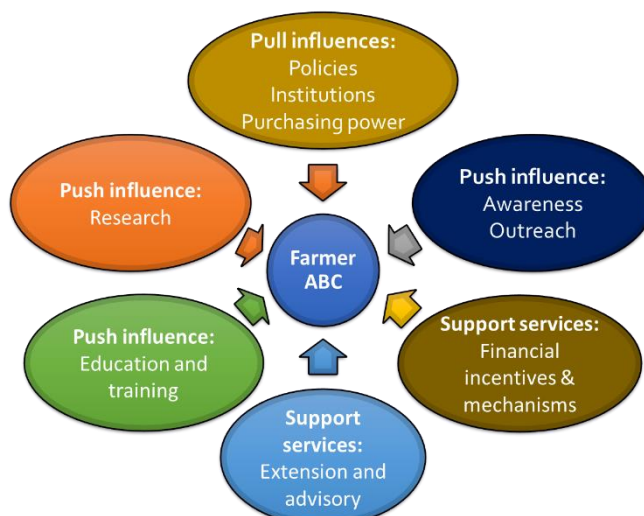


Figure 2.4 A 360-degree solution to support farmers' transition to CA/RA

However, some of the 'push influences' and 'support services' shown in this comprehensive 360-degree model above, should form the pillars of any CSRA capacity-building initiative. Henceforth, in this proposal they form the core elements or pillars in a two-prong approach aiming to accelerate the pace and quality of CSRA adaptation/adoption in South Africa through capacity building. This unique context-sensitive mixed-mode approach will follow a fine balance between the two pillars, which are delivered in a blend of practical, hands-on, individual and group sessions, and online sessions, strengthening existing initiatives and institutions' capacity and momentum continuing as long as necessary into the future.

Based on a farmer-centred systems approach concept, the following high-level description or framework for a training and extension strategy to support farmers in CSRA in the grain industry is proposed (a similar model would be applicable in the other industries).

Work package 1: On-farm CSRA innovation through experiential learning and adaptation

The activities of work package 1 are:

1. Diagnosis and analyses (of on-farm contexts)
2. Joint on-farm experimentation and discovery learning
3. Participatory monitoring
4. Data analysis and reflection
5. Communication and reporting

Work package 2: Hands-on CSRA discovery learning, skills development, and information sharing

The activities of work package 2 are:

1. A series of webinars and in-field discovery learning and skills development events
2. Participation and presentation at several farmers days

Expected results

Primary outcome for this project:

- Enhanced CA/RA capacity in the summer rainfall mixed crop/livestock production areas of South Africa by addressing the acute shortage in awareness and capacity in CA/RA.

Lead objective:

- To address the acute shortage in awareness and capacity with respect to i) on-farm applied capability, and ii) technical know-how and skills across South Africa's mixed crop/livestock production sector concerning CSRA.

Potential other expected outcomes for this strategy

Short-term (implementation period):

- Enhanced on-farm CSRA innovation through experiential learning and adaptation.
- Enhanced hands-on CSRA discovery learning, skills development, and information sharing.

Medium-term:

- Improved adaptation and implementation of CSRA in different mixed crop/livestock production systems across South Africa.

Long-term:

- Improved soil health and biodiversity, lower carbon footprint, better climate resilience, and improved and sustained production and profitability in different soil and climatic conditions, even in the semi-arid summer rainfall production areas of South Africa.
- Improved state and resilience of South Africa's summer rainfall mixed crop/livestock production areas in terms of its water, carbon and nutrient cycles and rural livelihoods.

Chapter 3 The cost and benefits of CSRA within grain crop production

3.1 Reasoning behind the move from conventional to climate smart regenerative agriculture

The United Nations considers climate change the defining issue of our time (United Nations 2025). While climate change is an issue that we can truly say affects everyone on the planet, people and industries that directly rely on the affected factors (i.e. rainfall, extreme weather events, average annual rainfall, rainfall distribution) will feel the effect of climate change earlier, and potentially to a harsher degree than others. The loss of soil organic carbon (SOC) to the atmosphere due to tillage contributes to the greenhouse effect and soil degradation (Lal 2004). Swanepoel et al. (2016) found a decline of 46% of SOC in cultivated fields in South Africa which severely affects the ability of the country's arable land to sustain food production in the future.

Adapting agricultural systems to changing climate conditions and mitigating its harmful effects are key to ensure both profitability and sustainability of the agricultural sector. According to Lal (2004), an effective mitigation strategy would necessitate sequestering almost all anthropogenically generated CO₂ through safe, environmentally acceptable and stable techniques with low risks of leakage – CSRA is an ideal choice for this purpose. Furthermore, to adapt to climate change farmers should adopt CSRA practices to build up climate resilience and various other ecosystem functions and services. As seen above and from Smith (2021), the adoption of CSRA in South Africa has been encouraging, helping farmers to realise multiple benefits, as described below in more detail.

3.2 Benefits of climate smart regenerative agriculture

Having expanded on the 'what' and the 'how' of CSRA, it is irrelevant without a good reason to change from current practices to CSRA practices. Multiple studies have been done to quantify the costs and benefits of CSRA and Figure 3.1 summarises the key benefits, while a more detailed discussion follows below. Figures 3.2 and 3.3 provide a quick outline of the interactions and benefits of the key principles listed in Section 3.2.

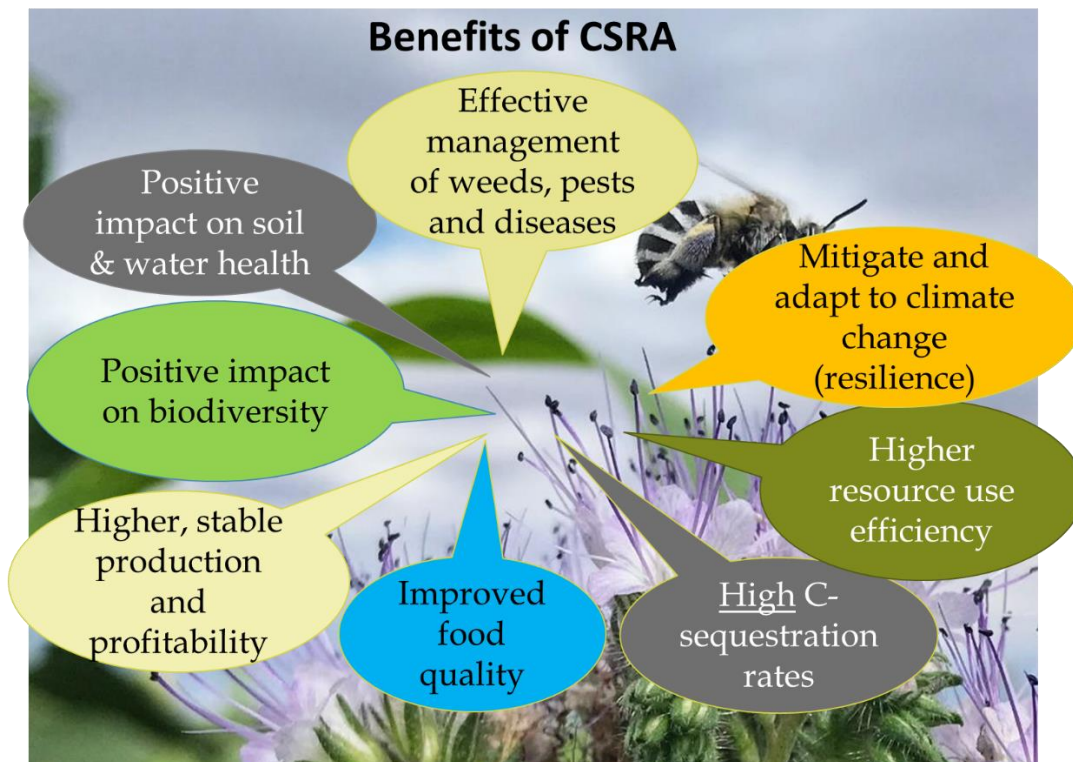


Figure 3.1 Benefits of/motivation for the adoption of CSRA

As multifaceted as the CSRA approach is, so multifaceted are the potential benefits thereof. We will attempt to outline them below in three categories: environmental, social and financial, although some points may be repeated. See Figure 3.4 for a summary of all the benefits.

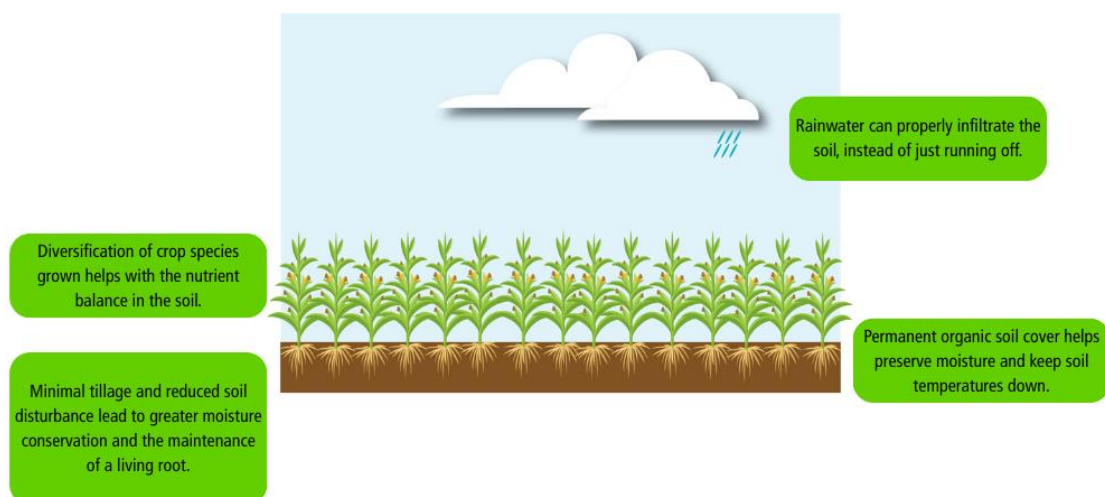


Figure 3.2 The benefits and interaction of CA principles

Source: Own analysis

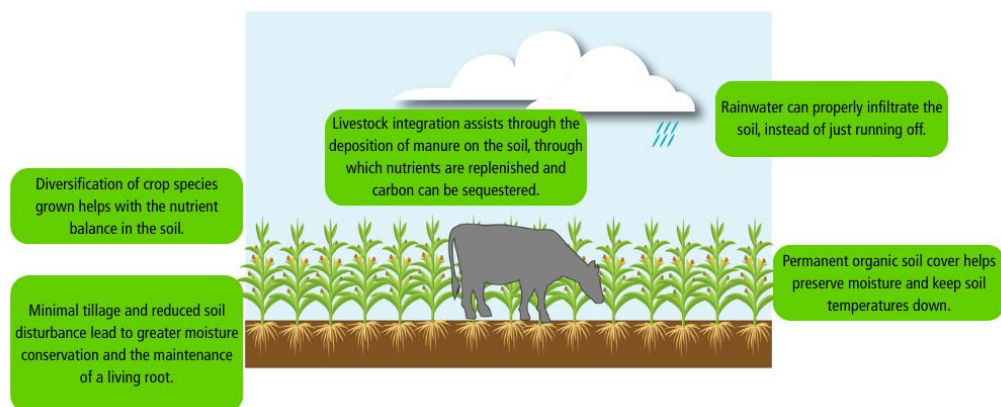


Figure 3.3 The benefits and interaction of RA principles

Source: Own analysis

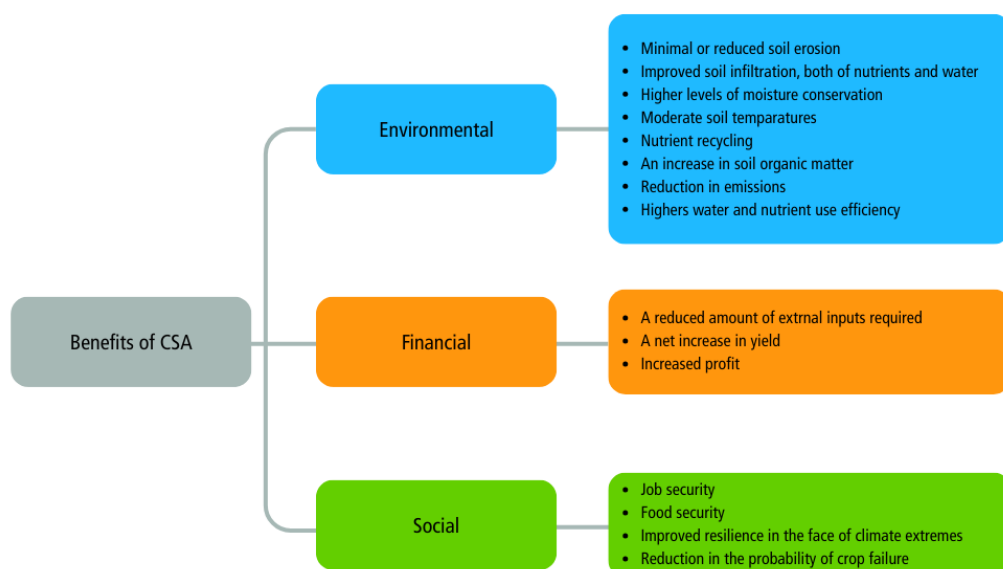


Figure 3.4 An illustration of how the possible benefits is organised into the environmental, social and financial categories

3.2.1 Environmental

Benefits

Tillage is bad for the soil. It is arguably the most degrading agricultural practice, because any soil disturbance immediately triggers the downward spiral of soil degradation, which starts with the removal of soil cover and the loss of soil organic carbon. What follows are the destruction of soil structure (aggregates) and the collapsing (slaking) of soil pores and channels, leading to compaction and soil surface sealing (crusting), which reduce infiltration, creating much more water runoff and soil loss through erosion. Minimum soil disturbance immediately arrests this prime cause of the downward cycle of soil degradation (see Figure 3.5).



Figure 3.5 *Minimum soil disturbance or no-tillage immediately arrests this prime cause of the downward cycle of soil degradation*

Soil should always be covered by growing plants and/or their residues, and soil should rarely be visible from above. A mulch keeps the soil cool and moist which provides favourable habitat for many organisms that begin residue decomposition by shredding residues into smaller pieces (see Figure 3.6). A good soil cover protects it against water and wind erosion, stops water from running off or evaporating and allows it to infiltrate into the soil (Maluleke et al. 2024). It also supports the build-up of soil organic matter (SOM). Soil cover enriches the soil through nutrient recycling and suppresses weed growth (Chepkemboi Waswa & Mulyungi 2021).

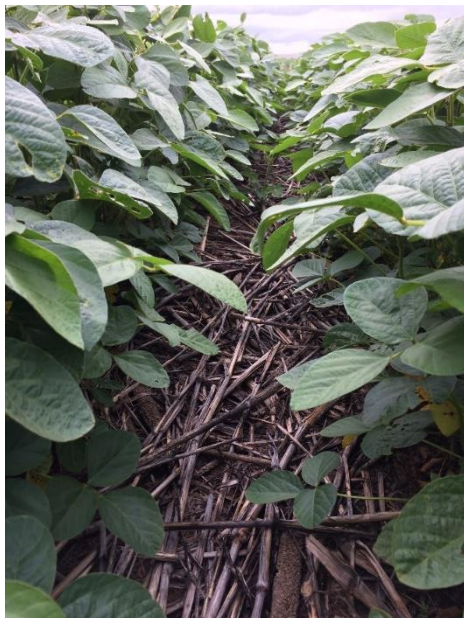


Figure 3.6 *Keep the soil covered with living or dead plants*

Under CSRA there is a net increase in SOM, the key driver of production, sustainability and resilience. As mentioned above, a significant portion of SOM has been lost in all arable soils due to tillage and while its restoration under CSRA is slow during the transformation period, it will increase over time. SOM improvements lead to improved soil structure, higher water and nutrient storage capacity, as well as biological activity. Swanepoel et al. (2017) mentioned several studies in South Africa that confirmed the positive effect of various CA treatments on SOM or SOC and soil fertility.

CSRA leads to SOC being sequestered and reduced GHG emissions (Jacobs et al. 2022; FAO 2025b; Smith et al. 2021a). There is a particular reduction in carbon dioxide as well as nitrous oxide emissions (Llanilo et al. 2020). Figure 3.7 shows the net carbon sequestration potential or net carbon footprint measured in net CO₂ emissions in different South African maize-based systems and regions as assessed by Smith et al. (2021a). It shows what happens when a producer transitions from the CT system to a CSRA (indicated here as the future CA–FCA) system. All CSRA systems do increase the carbon sequestration potential but only in the case of the smallholders did the sequestration exceed the emissions. In all other cases, the priority should be to reduce emissions and improve CSRA implementation. However, Mulimbi et al. (2023) emphasised and showed that CSRA leads to multiple environmental improvements over conventional production, a large addition to the literature which previously only looked at GHG emissions.

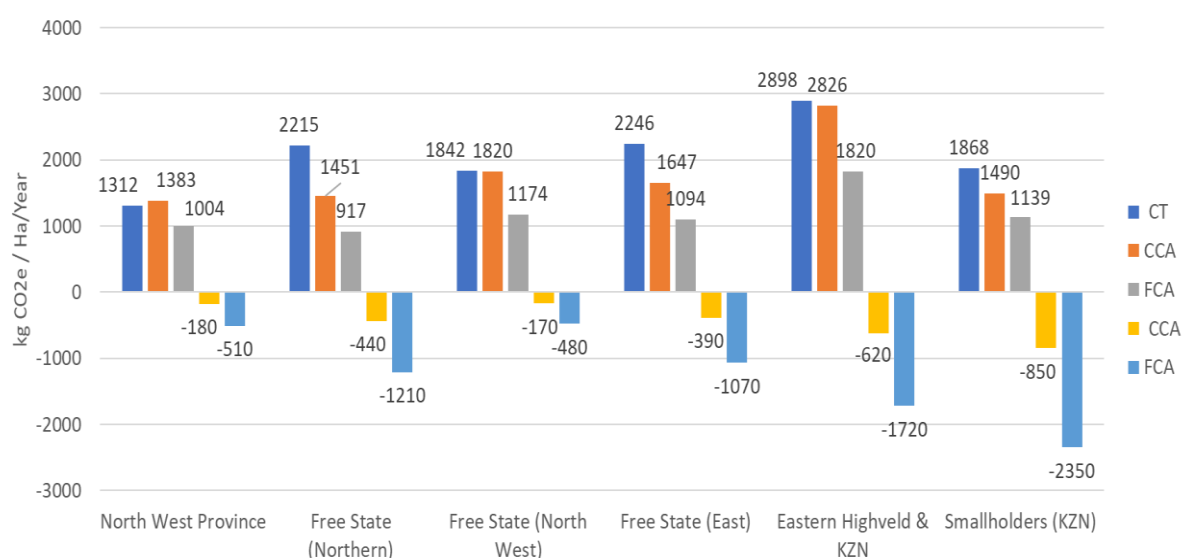


Figure 3.7 Current CO₂ emissions for each system vs. the sequestration potential of transitioning to CSRA/FCA farming systems for maize per region in South Africa

Source: Smith et al. (2021a)

Figure 3.8 demonstrates the potential SOC sequestration achieved by changing from CT to CA systems. As expected, CT systems showed the lowest soil carbon stocks for each region. The transition from CT to integrated CSRA systems resulted in increased SOC stocks. The CSRA (FCA) system holds the most carbon stocks compared to the other systems (Smith et al. 2021a).

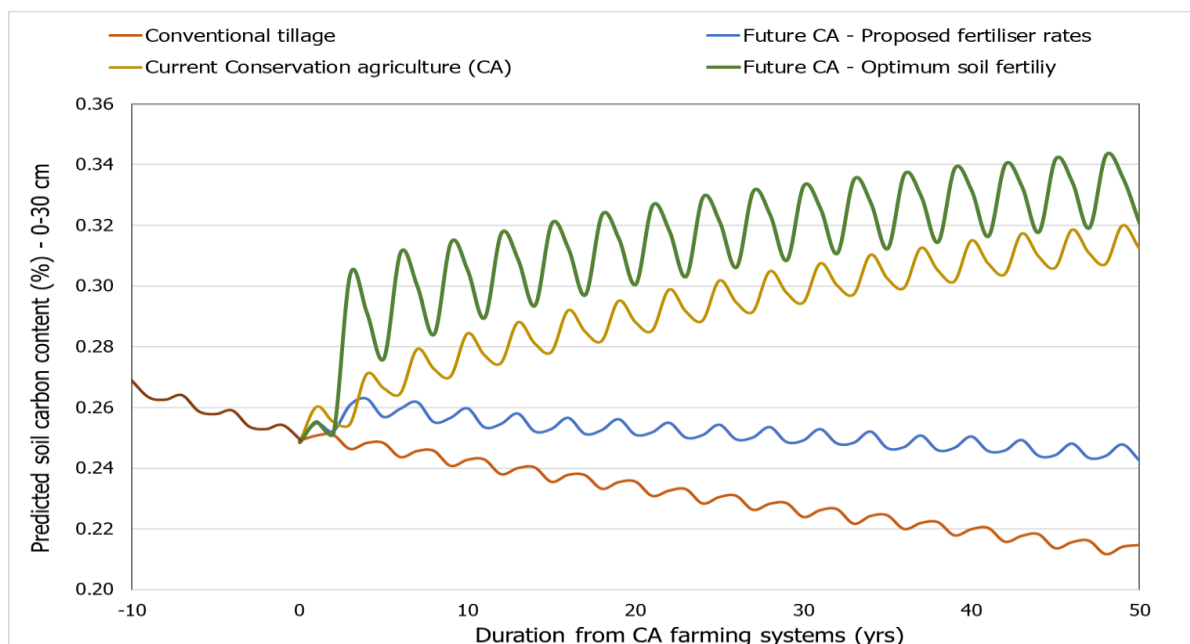


Figure 3.8 *Different SOC sequestration potentials under different maize-based systems in the North West Province of South Africa*

Source: Smith et al. (2021a)

Diversified cropping systems have multiple functions and benefits and could rightly be seen as the driver of CSRA (see Figure 3.9). The main aim is to maximise photosynthetic capacity, which is the amount of light intercepted by green leaves in a given area (determined by percentage of canopy cover, plant height, leaf area, leaf shape and seasonal growth patterns). Maximum photosynthetic capacity is a function of crop density and diversity, which means the more different types/species of plants and/or leaves covering as much of the soil surface as possible (ideally 100%) to absorb sun energy, the higher the capacity. On agricultural land, photosynthetic capacity can be improved through the use of multi-species cover crops, crop rotations, animal integration, multispecies pastures and strategic grazing. Bare soil has no photosynthetic capacity. Bare soil is also losing carbon (a net carbon source) and is vulnerable to erosion by wind and water. Bare soil increases the temperature and reduces rainfall in the landscape.

Crop rotation/intercropping in the same field increases water use efficiency, reduces the incidence of crop-specific pests and because different plant species make use of different nutrients, some (e.g. legumes which are nitrogen fixers) can help to restore the concentration of certain depleted nutrients in the soil after a crop that makes use of the nutrient (e.g. maize) was planted in the same field. Swanepoel et al. (2017) reported varied results of CSRA regarding productivity in South Africa. Yields were strongly related to soil and climatic conditions, and thus significantly affected by seasonal rainfall, tillage and cropping system as well as fertiliser interaction with CA. The latter factors indicate the critical role of management in the efficiency and impact of CSRA systems.



Figure 3.9 *Crop rotation/intercropping / cover crops have multiple functions and benefits and could rightly be seen as the driver of CSRA*

Integrating cropping and livestock systems have benefits both in terms of crop and of animal production. Focusing on the crops, an integrated system can lead to a reduction in water use (in irrigated systems), less soil erosion, fewer external inputs (fertiliser) required as well as greater rainfall infiltration/retention. Livestock integration's aim is to take the effect and benefits of the other CSRA principles to an even higher level, implying that the harvesting of sunlight for growing crops and building soils is optimised. Livestock (e.g. cattle, sheep, pigs, chicken, etc.) utilising cover crop mixtures and natural pastures, for example, is part of a natural ecosystem and thereby contributes to diversity. With high density grazing utilising 30–50% of available material (it might be higher in natural pastures), livestock can stimulate root development and recycle 80% nutrients in the form of dung (see Figure 3.10).



Figure 3.10 *Integrating cropping and livestock systems have benefits both in terms of crop and of animal production.*

The nutrients from animal urine and faeces count positively to soil and plant development, where oftentimes it is considered a harmful by-product (Sanderson et al. 2013). From a South African perspective, Strauss et al. (2021) and Smith et al. (2021b) supported by global data (Lal 2015), found that diverse CA crop-livestock systems, but particularly livestock, have a huge positive effect on soil biology, the soil food web, improving key soil properties to critical threshold levels resulting in the restoration of essential soil functions and services, such as soil carbon sequestration, soil nutrient cycling, above- and below-ground biodiversity, the water infiltration rate, water runoff and erosion, weed management and the reduction of soil borne diseases (Du Preez et al. 2025). Beukes et al. (2019) found sharp increases in percent SOC (from 0.48% to 0.64%) within three years on the hot, sandy soil conditions in the northwest Free State using summer and winter multispecies cover crop systems (without livestock), showing the potential of CA for soil carbon sequestration even in those conditions. In the current CA FIP trials employed throughout the summer rainfall production regions in South Africa, an increase in SOM under CSRA systems were found within 4 years, and some cases even within two years (<https://assetresearch.org.za/conservation-agriculture/>).

There are many sources of food in the soil that feed the soil food web, but there is no better food than the liquid carbon exuded by living roots (see Figure 3.11). This liquid carbon depends on the photosynthetic capacity of the cropping system as explained above. Every plant exudes its own unique blend of liquid carbon, comprising various biological compounds, such as sugars, enzymes and amino acids. Soil organisms feed on this liquid carbon from living plant roots first. Next, they feed on dead plant roots, followed by above-ground crop residues, such as straw, chaff, husks, stalks, flowers and leaves. Lastly, they feed on other organisms lower in the soil food web. The greater the diversity of food for the microbes, especially from living plant roots as their main source, the healthier and more active the soil food web.



Figure 3.11 *Liquid carbon exuded by living roots feed the soil food web.*

A healthy soil food web is essential for the provision of multiple functions and services of a healthy soil, such as an increase in plant available nutrients (fertility) and stable soil aggregates (structure or

a soil sponge) with a higher infiltration, soil water holding capacity and drought-resilience. In degraded or eroded soils large amounts of fertiliser/pesticides/irrigation must be used to keep yields at a viable level. The use thereof can lead to pollution, health problems, habitat destruction and many other possible infrastructure damage. CSRA, especially moving to organic forms of it, can stop the damage and degradation from worsening and eventually reverse some of it – the direct damage that was done on-farm. This has both environmental and financial benefits, as over time the cost of transitioning to a climate smart farming system will be recouped through increased yields. Mulimbi et al. (2023) found that no-till is 229%, 102% and 55% more efficient at converting environmental damage into a kilogram of wheat than conventional tillage under poor, average and good yielding scenarios in the Western Cape of South Africa, respectively.

Costs

Blignaut et al. (2024) did a survey among both CT and NT/CA maize farmers to understand what the farmers' perceptions are of the two different management methods. When considering only the cost, the key takeaway is that the profitability of NT/CA is questioned by most CT farmers, whereas the majority of NT/CA farmers state that it is the more profitable of the two methods, as shown in Figure 3.12.

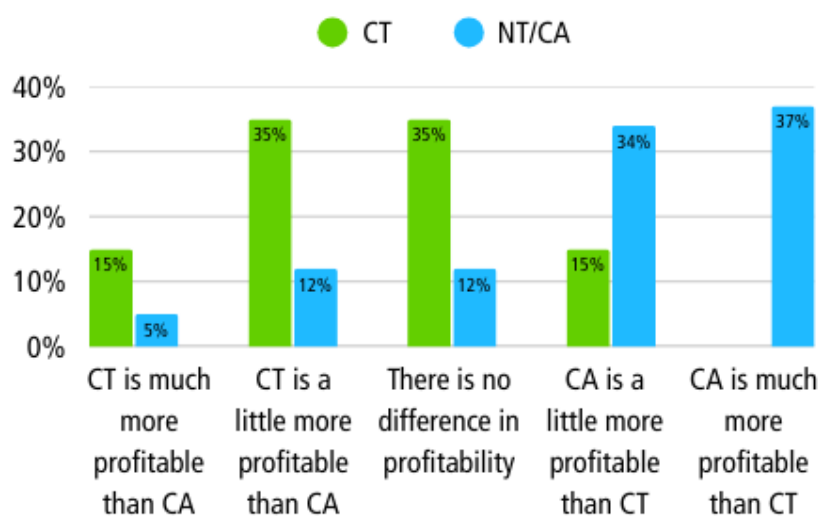


Figure 3.12 The perception of profitability of CSRA and CT among farmers

Source: Blignaut et al. (2024)

To change the perception noted above, information and education are needed. The resistance to change is in part due to the perceived safety in what is known, as opposed to the unknown, as well as limited support from the financial sector in terms of insurance/loans. Due to the resilience that CSRA builds into soil, the inherent risks decrease over time as a farm will be less affected by climate extremes if the soils are in a healthy state. This is not yet reflected in an insurance package for CA/RA

farms. In terms of loans, to transition from conventional agriculture to CSRA will result in a short-term decrease in revenue while soil and the on-farm ecosystems must adapt to being “self-sustaining” under a CSRA system, rather than relying on external inputs. Financing for a transition such as the above is of limited availability.

Blignaut et al. (2024) found that there were varied responses to the duration of time it took before farmers observed any positive changes or benefits following the initial dip (J-curve) in productivity or income (see Figure 3.13) after transitioning to CSRA. The results indicate that most farmers saw positive changes in erosion, lower machinery maintenance and replacement costs, and increased soil water and climate/weather resilience between 1 and 2 years. Knowledge and skills, soil health and fertility, lower production input costs, and improved biodiversity were found, by most farmers, to yield benefits after 3 to 5 years. Positive changes or benefits from financial profits and production/yields were said to mostly translate between 1 and 5 years with some farmers indicating it took them between 6 and 10 years.

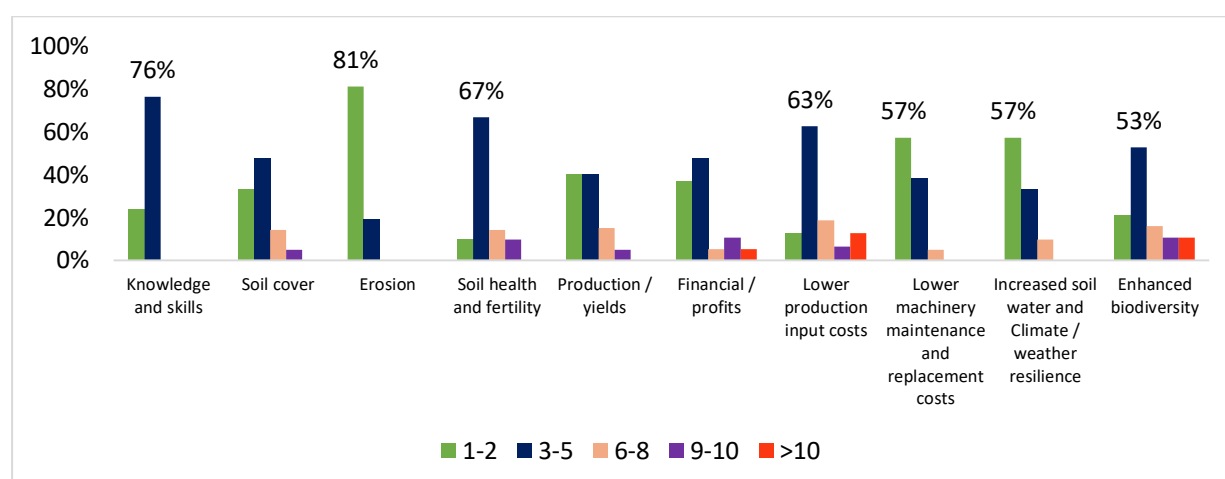


Figure 3.13 *The duration of time it took before farmers observed any positive changes or benefits following the initial dip in productivity or income*

Note: Farmers were asked to indicate their answers on a scale of 1 to 10 years, with an additional option of more than 10 years as well. The green bars reflect the percentage of the sum of the 1s and 2s out of the total number of responses received; the blue bars reflect those of the 3s to 5s; the light brown bars those of the 6s to 8s; the purple bars those of the 9s and 10s; with the red bars reflecting those greater than 10. The percentage add to 100%, and the highlighted colour bars indicate the major reasons.

Without accounting for the environmental services provided by CA adoption, producers and policymakers may think that conventional tillage is the correct practice to adopt and endorse for long run sustainability. When accounting for the environmental services from switching from CT to CA, zero and no-till have a 90% and 86% chance of being more profitable than conventional tillage, respectively (Mulimbi et al. 2023).

3.2.2 Financial

Derpsch (n.d.) emphasised the correct protocol and research questions when making economic comparisons between conventional tillage (CT) and CSRA. Firstly, “we cannot just compare one growing season. We have to compare the whole system over several years and give a monetary value to such things as loss of SOM and soil fertility in CT compared to gains in organic matter content of the soil and improvement of soil fertility in NT”. If economic analysis of CSRA is performed the following questions should be asked (Derpsch n.d.):

- Have all aspects been included that affect economic performance of a system over several years?
- Has soil erosion (degradation and loss of productivity) in CT versus soil building (improvement of soil fertility) in a CSRA system been considered?
- How do we rate losses of SOM in the soil (and CO₂ emissions) in CT as against build-up of SOM (and carbon sequestration) in a CSRA situation?
- Are we considering yield increases with time in CSRA as against decreases in CT?
- Are we considering the lifespan of a tractor which normally is 8–10 years in CT, against 16–20 years in CSRA?
- Are we considering the size of the tractor and the horsepower/ha needed in both systems?
- Are we considering savings in fuel when practicing CSRA as compared to fuel costs in CT systems?
- Are we considering that cost of building and maintaining mechanical infrastructure (contour banks, terraces, grassed waterways) will be drastically reduced in CSRA because of higher water infiltration rates and less runoff in this system?

Benefits

According to Tebrügge and Böhrnsen (1997), the following economic advantages have been found when comparing CT to CSRA in long-term soil tillage field experiments in Germany:

- Investments for machines are 39% lower
- Power requirements are 75% lower
- Working time is 80% lower
- Fuel consumption is 84% lower
- Variable costs: wages are 84%, fuel is 85% and repair costs are 65% lower
- Fixed costs: tractor is 86% lower, stubble cultivation is 100% lower, soil tillage and sowing are 27% lower

As was shown in similar studies in South Africa (Maluleke et al. 2024; Mulimbi et al. 2023), these values will certainly change from one country to the other and also from one region to the other, but probably in most parts of the world the trends will be the same.

It is important not to forget the offsite costs that occur when using conventional agriculture and the offsite benefits of using the no-tillage technology as for instance (Sorrenson et al. 1997):

- Lower water treatment cost through reduced sedimentation in rivers (for domestic and industrial use)

- Longer life of reservoirs used for electricity generation through reduced siltation
- Reduced dredging cost at ports due to reduced river siltation

Sorrenson et al. (1997) furthermore showed that there are additional benefits from adopting CSRA in place of CT systems. These include: (i) reduced tractor hours and lowered permanent farm labour and machinery costs; (ii) savings in fertiliser, insecticide, fungicide and herbicide usage per crop over time in NT compared to CT; and (iii) cost savings in NT through eliminating contour terracing and the replanting of crops following heavy rain which is often needed under CT.

The key point to note with CSRA is that over time the practices mentioned above improve ecosystem functions, such as soil health, which will provide free services, such as nutrients and water, while it increases or sustains yield (Lal 2020). The net result is producing more with less, with higher profit margins. This will not be an immediate change, but as ecosystem functions and services are restored over a period of 3–10 years (depending on the context), less inputs are needed, with sustained stable yields and higher profits.

Minimal/no till cuts the production cost by reducing the fuel and labour needed per field. There is also a drop in fertiliser usage due to increased soil fertility (FAO 2010a). Due to the combination of higher yield and cost savings the local economy is also stimulated due to better cash flow.

Cover crops and mulching assist with the suppression of weed growth, so over time there will be a decrease in unwanted seed load, further reducing the labour required and hence cost (FAO 2010a). Depending on the crop and market, there is oftentimes a premium on crops that were produced with no external/chemical inputs (Lohr 2002). This combined with the reduction in input cost leads to further financial benefits.

Over the medium- to long-term less cultivation practices and farming equipment is needed, resulting in decreased machinery depreciation, replacement and maintenance costs (FAO 2010a; Maluleke et al. 2024). In a conventional system multiple primary and secondary tillage passes would be needed, as the soil has to be prepared, and planting, fertilising and pest control need to be done. In a CSRA system the use of equipment and field actions are greatly reduced. The possible reduction in input costs such as agro-chemicals and fuel by adopting a CSRA system is up to 43% (Jacobs et al. 2022). Maluleke et al. (2024) showed that CSRA can relieve farmers of enormous financial risk that has the potential to grow exponentially over the medium- to long-term by prioritising the restoration of soil and ecosystem goods and services. Various studies have proven that CSRA can reduce a farm's heavy reliance on expensive inputs, offer significant cost savings and loss-avoidance, and provide supplementary profit generating opportunities through additional livestock and feed revenue.

The results of the study done by Maluleke et al. (2024) also corroborated existing studies by providing evidence-based support that indicates that, relative to CT and NT, CA/RA (or CSRA) offers the best/maximum return on investment in absolute terms, and even more so on a risk-adjusted basis.

In the Western Cape, South Africa, the life cycle analyses (LCA) study done by Mulimbi et al. (2023) indicate that for every kg of wheat produced in Langgewens trial there was R0.89 and R0.65 in environmental damage under no-till and zero-till wheat production, respectively. In Tygerhoek there was R0.71 and R0.60 in environmental damage under no-till and zero-till wheat production, respectively. The single scores for conventional tillage wheat production were R2.92, R1.80 and R1.37 per kg in environmental damage in a poor, an average and a good yield scenario, respectively, in Langgewens. These findings suggest that CA wheat production has a lower environmental impact than conventional wheat production and, among CA systems, zero-till has a lower environmental impact than no-till.

Costs

Although CA can reduce the amount of diesel requirements in production, empirical evidence has shown that CA can increase weed infestation and CA crops can benefit from an increase in herbicides use. Under CA, the efforts to control weeds in eastern Free State were significantly higher per hectare more in herbicides. A 2015 survey of commercial wheat farmers in Western Cape, indicated 60% reported increased weed control costs while 40% spent more on pest and insects control as a result of implementing CA (Mulimbi et al. 2023).

One of the points mentioned above is decreased machinery cost. While this holds, there could be an initial investment needed for the adaptation of machinery (e.g. adapting wheelbases to practice controlled traffic farming (CTF) or the purchase of suitable CSRA-friendly equipment such as no-till planters).

Should the practitioner want to reduce the amount of external inputs such as herbicides, then there will also be an initial drop in revenue during the transition period due to higher weed growth. There is an observed decrease in unwanted seed load, but this happens over time as the CSRA system reaches equilibrium.

3.2.3 Social

Benefits

According to Putter et al. (2014), CSRA is a way of farming in which producers, as per usual, have to invent, adapt, apply and learn things within the constraints of their own circumstances and situations.

Just as there isn't a universally applicable blueprint for raising children, so too there aren't off-the-shelf instruction manuals specifically suited to each and every aspect of each and every farm or producer. When producers reach this level of innovation, they are able to "predict their own future by inventing and improving it on a daily basis", which lead to the following socioeconomic and environmental benefits:

- Is practical for all kinds of producers
- Increases net farm income
- Yields better returns on investment
- Immediately increases disposable family capital
- Stabilises communities
- Increases farming systems resilience
- Diversifies human and animal food flows
- Minimises labour requirements
- Alleviates the burden born by women
- Mitigates the impact of HIV/AIDS
- Increases and protects biodiversity
- Is a key driver of sustainability by preserving natural capital
- Empowering and nurturing the ecological literacy (ecolacy)

It is exciting to realise that the list above includes direct social benefits attributable to the CSRA system, among other clear economic and environmental benefits discussed above. Llanilo et al. (2020) document a case study where severe soil erosion around the Itaipu bio-national hydroelectric power plant had massive repercussions on the expected lifetime of the reservoir. However, due to the concentrated efforts of the government and farmers located around the reservoir in the implementation of soil conservation practices and restoration of the natural environment around the reservoir the expected total lifetime of the reservoir has increased from 139 years to 191 years. This shows that the impact of CSRA practices is not limited to the farm where these are practiced but can have much wider landscape and societal impacts.

The benefits and mechanisms described above have been extensively experienced and researched, in part driving the upswing in the adoption thereof. In South Africa, there is a substantial portion of field crop farmers who have switched and are switching to CSRA (Smith 2021), showing an adoption trend of potentially many more farmers to follow.

Costs

In general, CA is associated with positive outcomes; however, Strauss et al. (2021) and Swanepoel et al. (2017) mentioned various research results on unintentional drawbacks, such as soil compaction layers, changing aspects of weed populations and dynamics, herbicide resistance and increased input costs. Other research showed that not reaching minimum soil cover levels had a negative effect on the uptake of CA, and questions remain about what the critical levels of residue should be in different regions, especially where livestock is included in the system. Some studies indicated no yield loss when there was a limited removal of residues. However, the positive impacts and returns of CA far exceed the negative experiences in almost every context around the world (Strauss et al. 2021).

The experiences mentioned above show that there is a host of potential costs in any on-farm scenario which require careful monitoring, understanding and management. These management considerations include effort and costs of education of the farmers and landowners, and the cost of transitioning. Some farmers may need new equipment or infrastructure and during the transition period between CT and CSRA there could be a drop in revenue which some farmers may require external input to bridge.

To reap all the benefits of CSRA farmers concomitantly need to markedly change their cropping systems, switching from monocropping practices to diversified crop rotations, which calls for learning an array of new crop management skills (Derpsch n.d.).

According to Sorrenson et al. (1997) the use of CSRA call for new management skills, particularly needed to cost effectively control weeds. Farmers require a number of years to master these skills, the key ones being: (i) type and quantity of herbicide used; (ii) regulation of sprayer pressure, output, speed and timing of herbicide application; (iii) the choice and sequencing of cash and green manure crops in rotations; (iv) minimising the time between harvesting and the sowing of a subsequent crop; (v) managing ground cover and crop residues; and (vi) using spot spraying with weed-specific herbicides or manual labour, where cost-effective, to control sporadic patches of weeds as opposed to blanket spraying with broad-spectrum herbicides. If these skills are not mastered, inevitably weed infestation increases, production costs rise and crop yields may fall, which combine to significantly erode farm profits. Farmers then revert back to CT methods as they attempt to survive for some more

time before reaching the inevitable point of having to abandon their land when it is no longer productive and economic to cultivate.

Blignaut et al. (2024) asked crop farmers in the summer rainfall area of South Africa to indicate the biggest challenges they faced during the transition period to CSRA. The majority indicated that they were making mistakes in implementing CA correctly and soil related challenges (e.g. too sandy). This was because of a lack of experience and knowledge, but can with time, experience and exposure to other operations, be overcome. Contrary to expectation, affected productivity (yields), financial constraints and weather-related challenges imposed the least challenge on most of the farmers (see Figure 3.14).

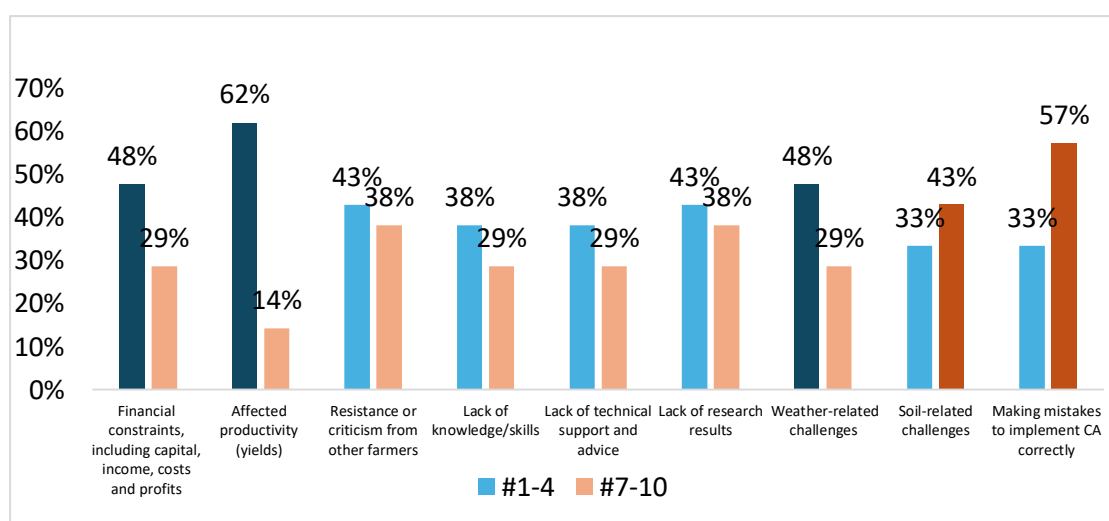


Figure 3.14 General challenges faced during the transition period

Note: Farmers were asked to indicate their answers on a scale of 1 to 10, with 1 = “no or little” and 10 = “very high”. The blue bars reflect the percentage of the sum of the 1s to 4s out of the total number of responses received, with the light brown bars the percentage of sum of the 7s to 10s. The percentage does not add to 100%; the balance being the sum of those that scored 5s and 6s. The highlighted blue and brown bars indicate the major reasons.

Farmers were also asked to indicate the level of difficulty they faced with implementing different CSRA practices during the transition phase (see Figure 3.15). The following principles were rated most difficult:

- Integrated weed management, living roots in the soil, integrated soil fertility and acidity management, and soil cover.

The principles they found least difficult to implement, are:

- Livestock integration, cash crop rotation, and access and use of CA machinery/implements.

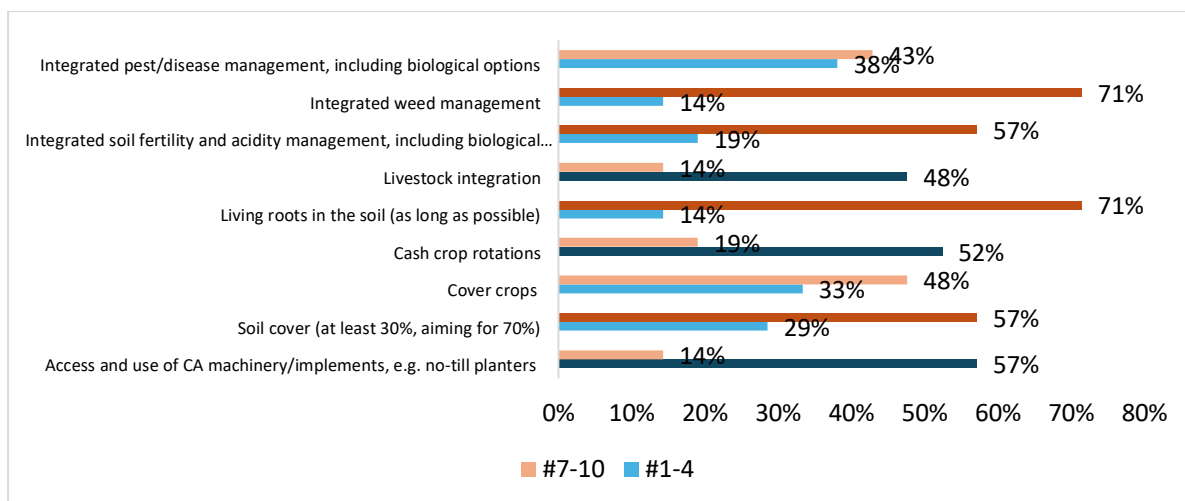


Figure 3.15 Level of difficulty farmers faced with different CA practices during the transition period

Note: The graph scales were treated like Figure 3.8.

Farmers were also asked to indicate how they managed to overcome a list of common challenges in the transition phase. To this, improvement of farmer's knowledge and skills; (on-farm) testing and adapting of CA practices, regular monitoring and evaluation of results; joining study groups or networks for support; and seeking assistance from research/technical experts, were used most to manage or overcome challenges during the transition phase. The strategies least used to manage or overcome challenges during the transition phase include using other sources of income and selling off other assets (see Figure 3.16).

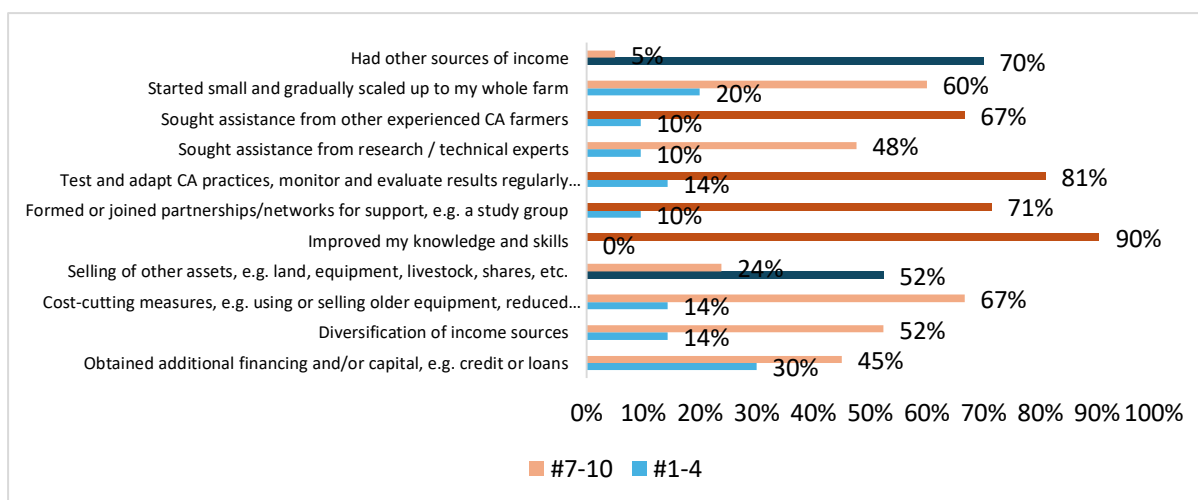


Figure 3.16 How farmers managed to overcome the above challenges during the transition phase (J-curve)

Note: The graph scales were treated like Figure 3.8.

In response to the question as to which resources and methods of support they found most useful, farmers indicate that most of the support services offered were found helpful (see Figure 3.17). However, CSRA conferences and farmers' days were found the most helpful followed by other

experienced farmers through cross-visits, etc., study groups (including WhatsApp groups), and social media (e.g. YouTube, Facebook, Internet websites, etc.). Interestingly, technical manuals, guidelines and publications were the least helpful relatively.

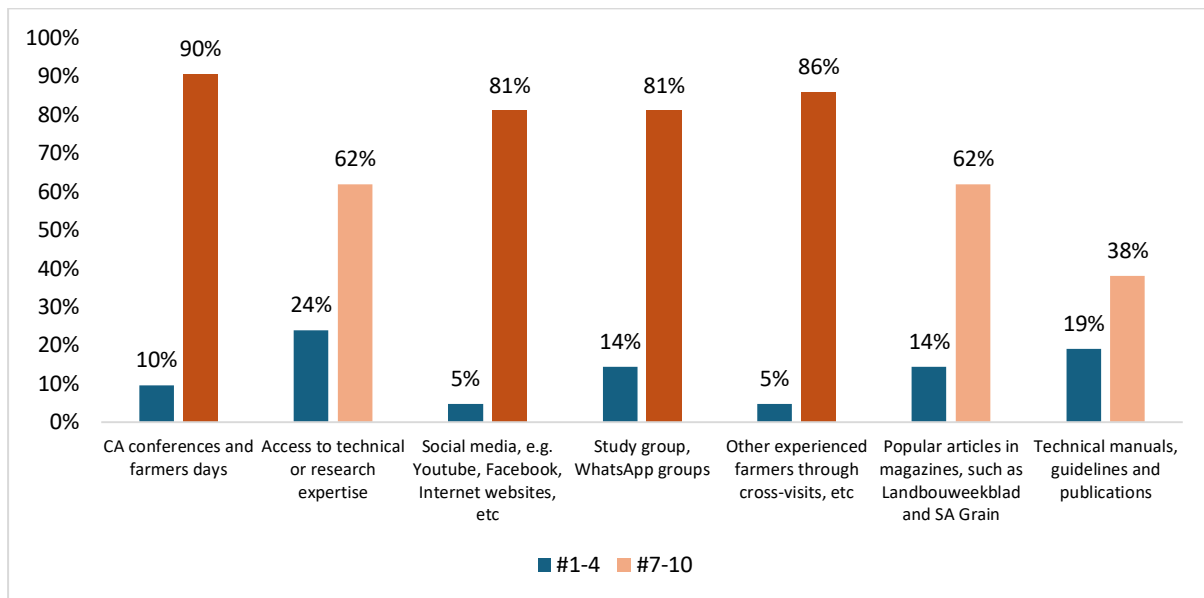


Figure 3.17 Support and resources most helpful for information and advice during the transition process

Note: The graph scales were treated like Figure 3.8.



Part B

LIVESTOCK PRODUCTION IN SOUTH AFRICA

Chapter 4 An overview of livestock production in South Africa

4.1 Introduction

4.1.1 Background

Livestock production plays a crucial role in South Africa's economy, providing employment, food security and export opportunities. Cattle farming is a major component of South Africa's livestock sector, contributing significantly to beef and dairy production. The country is the top beef producer in Africa and exports beef to various international markets. Dairy farming is a major agricultural industry, employing thousands of people and producing milk for both local consumption and export. Sheep and goat farming are important for meat, wool and mohair production with wool and mohair being significant export products. The poultry industry is one of the fastest-growing sectors, providing an affordable source of protein to the population. It includes broiler chickens and egg production, with significant exports of poultry products. Pig farming is another key sector, with pork production catering to both local and international markets. (Detailed information and data of livestock production in South Africa - production areas, trends, consumption, market structure, trade of different sectors – can be found in Annexure 5). The industry includes both commercial and small-scale farming operations. Other livestock sectors include ostrich farming, rabbit farming and aquaculture, each contributing to the diversity and resilience of South Africa's agricultural landscape.

Gross farming income, which was earned from agricultural production, increased by R6 186 million (1.4%) and was estimated at R452 100 million in 2023/24, compared to R445 915 million in 2022/23 (DALRRD 2024a). The increase was due to the increase in income from horticultural and animal products by 10.3% and 6.1%, respectively (DALRRD 2024b).

The weighted average price of animal products increased by 6.0% due to the increase in the price of poultry meat by 18.8%. The prices of slaughtered stock decreased by 4.7% and pastoral products by 4.1%, while the price of milk remained unchanged (DALRRD 2024b). The domestic terms of trade increased by 15.5% from 1.03 to 1.19 due to better prices that were received from agricultural products (DALRRD 2024b).

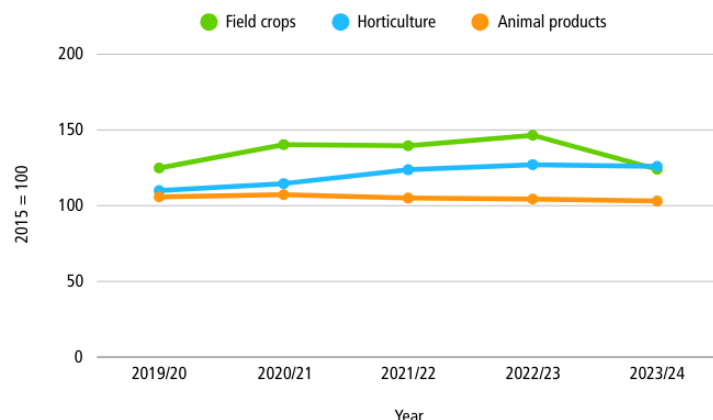


Figure 4.1 Volume index of agricultural production, 2019/20–2023/24

Source: DALRRD (2024b)

Volume of agricultural production: The estimated volume of agricultural production in 2023/24 was 5.0% less than in 2022/23 (DALRRD 2024b). Animal production, as explained by Figure 4.1, decreased by 1.3%, mainly because of the decreases in the production of eggs and poultry meat, as well as the number of stocks slaughtered (calves and pork) as compared to 2022/23 (DALRRD 2024b).

Producer prices of animal products: The weighted average price of animal products increased by 6.0% due to the increase in the price of poultry meat by 18.8%. The prices of slaughtered stock decreased by 4.7% and pastoral products by 4.1%, while the price of milk remained unchanged (DALRRD 2024b).

Gross value of animal production: The gross value of animal products contributed 43.2% to the total gross value of agricultural production, horticultural products 30.3% and field crops 26.5%. The poultry meat industry made the largest contribution with 15.4%, followed by maize with 12.9% and cattle and calves slaughtered with 10.4% (DALRRD 2024b).

Farming income from animals: The gross income from animal products, seen in Figure 4.2, increased by 6.1% and amounted to R193 869 million for the year ended June 2024, compared to R182 722 million the previous period. This was due to the increase in income from eggs by 19.0%, milk (12.9%) and poultry meat (10.0%). The income received from sheep slaughtered decreased by 6.0% and cattle and calves slaughtered by 3.2% (DALRRD 2024b).

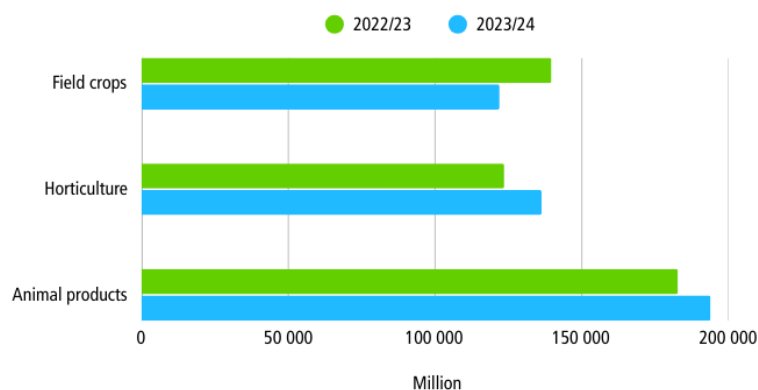


Figure 4.2 Gross income (R million) from agricultural sectors, 2022/23–2023/24

Source: DALRRD (2024b)

Climate smart regenerative agriculture (CSRA) is becoming increasingly important in South Africa, especially in the livestock sector. Some key points about CSRA in the livestock sector in South Africa includes (Choudhary et al. 2022):

2. Climate risks

The livestock sector faces significant challenges due to climate change, including rising temperatures, shifting rainfall patterns and increased frequency of extreme weather events. These changes impact livestock health and productivity.

3. Sustainable practices

CSRA involves adopting practices that increase productivity, enhance resilience and reduce greenhouse gas emissions. This includes improved grazing management, feed quality and water conservation techniques.

4. Government initiatives

The South African government, along with various organisations, are promoting CSRA through policies and programmes aimed at supporting farmers in adopting sustainable practices.

5. Research and development

Ongoing research is focused on developing and implementing CSRA practices tailored to the local context. This includes studying the impact of climate change on livestock and identifying effective mitigation strategies.

4.1.2 Institutional support for the livestock sector

Institutional support for the livestock sector is provided by various institutions, namely:

1. Institutional integration

The key national institution overseeing South Africa's livestock sector is the Department of Agriculture, Land Reform and Rural Development (DALRRD).

2. Animal health, research and marketing

Other state entities working alongside DALRRD on livestock matters include the Agricultural Research Council (ARC), the National Agricultural Marketing Council, Onderstepoort Biological Products SOC Ltd and the South African Veterinary Council (SAVC).

3. Public-private partnerships

The National Agricultural Marketing Council (NAMC) is a statutory body, accountable to the Minister of Agriculture, Land Reform and Rural Development and responsible for increasing international market access for agricultural products.

4. Multi-departmental interventions

Recognising the potential of livestock in driving job creation and meaningful economic transformation and growth, the Department of Trade, Industry and Competition (DTIC).

5. Access to finance

Access to finance for South Africa's commercial and emerging farmers can be gained through the Industry Trusts at NAMC, directly through DALRRD, some private sector associations, and from the Land and Agricultural Development Bank of South Africa (Land Bank).

6. Cooperation with private and professional associations

In the cattle sector, the South African Meat Processors Association (SAMPA), National Emergent Red Meat Producers' Organisation (NERPO) and South African Meat Industry Company (SAMIC) convene value chain actors to create a more inclusive and sustainable industry. Other institutions relevant for sheep and goat production are the SA Mohair Growers' Association (SAMGA) and the National Wool Growers Association of South Africa (NWGA). Other industry associations supporting diverse aspects of livestock value chains include the Red Meat Producer Organisation, South Africa Feed Lot Association, Animal Feed Manufacturers' Association, South Africa Poultry Association, Milk Producers' Organisation and South African Milk Processors Organisation (SAMPRO).

More information about how different stakeholders and institutions such as government, industry and farmer bodies, research entities and others are involved in climate smart livestock agricultural activities can be found in Annexure A7.2.

4.2 Different segments within the livestock sector

4.2.1 Beef and dairy cattle, sheep, goats, poultry and pigs

The number of cattle, sheep and pigs increased by approximately 0.20%, 0.01%, and 0.68%, respectively, while goats decreased by approximately 0.35% between August 2022 and February 2023 (DALRRD 2023g, 2024b).

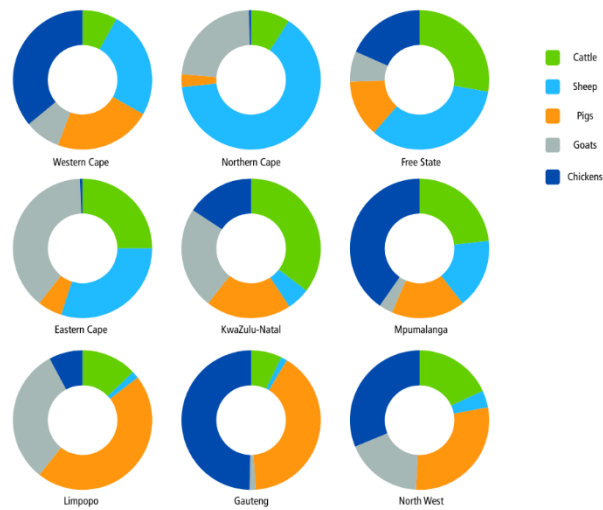


Figure 4.4 Livestock percentages in different provinces
Source: DALRRD (2023e)



Figure 4.3 Classification of major livestock sectors
Source: DALRRD (2024b)

Imports and exports of agricultural products: During 2023/24, the Netherlands, with exports to the value of R24 506 million, the United Kingdom (R16 757 million), Zimbabwe (R14 907 million), China (R13 817 million) and Botswana (R13 553 million) were the five largest trading partners of South Africa in terms of export destinations for agricultural products. The five largest trading partners for South Africa's imported agricultural products during 2023/24 were Thailand (R9 720 million), China (R8 172 million), Eswatini (R7 568 million), Brazil (R7 472 million) and Indonesia (R7 282 million) (DALRRD 2024b). The exports and imports of different livestock in various countries is seen in Figures 4.5 and 4.6.

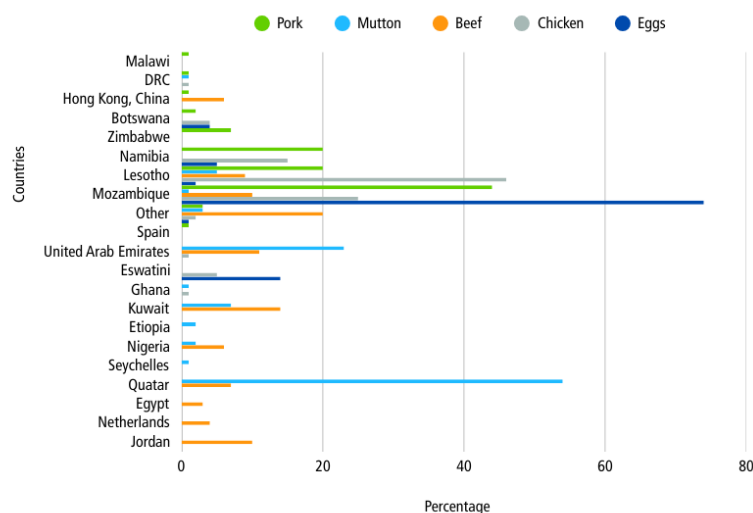


Figure 4.5 Export percentages of livestock to other countries
Source: DALRRD (2024b)

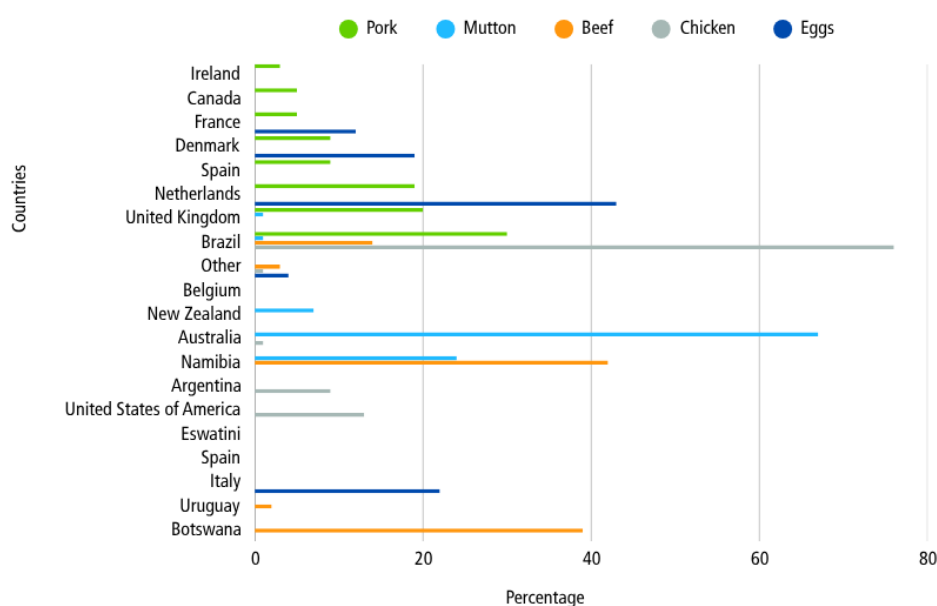


Figure 4.6 Import percentages of livestock into South Africa

Source: DALRRD (2024b)

Trade relations/(opportunities) between South Africa and the Netherlands

The Netherlands often serves as a gateway to Europe for South African agricultural products. Some key points include (summary in Table 4.1):

1. Netherlands imports

Meat and Meat Products: Export of South African meat to the Netherlands is modest due to strict EU regulations, but there is a growing interest in specialty meat products (DALRRD: Directorate Statistics and Economic Analysis 2023).

2. Netherlands exports

Dairy Products: The Netherlands exports milk powder, cheese and other dairy goods to South Africa.

Animal Feed and Supplements: High-quality feeds and nutritional supplements support the South African livestock industry.

Technology and expertise: Innovations in livestock farming, such as automation and sustainable practices, are shared between the countries (DALRRD: Directorate Statistics and Economic Analysis 2023).

3. Mohair market leader

South Africa is the world's largest producer of mohair, and the Netherlands is a significant importer (DALRRD: Directorate Statistics and Economic Analysis 2023).

4. Genetic improvement

Collaborative projects between Dutch and South African institutes aim to improve livestock breeds for better yields (DALRRD 2024b).

Table 4.1 *Summary of the trade between the Netherlands and South Africa*

Category	Trade with the Netherlands	Numbers to/from South Africa
Cattle	Export of specialty beef breed	14 million
Sheep	Wool trade, especially Merion wool	28 million
Goats	Mohair exports	6 million
Poultry	Import of technology	Growing annually

Source: DALRRD (2024b); DALRRD: Directorate Statistics and Economic Analysis (2023)

4.2.2 Other livestock farming

Other livestock farming, not discussed herein, is summarised in Figure 4.7, and include ostrich and rabbit farming as well as aquaculture.

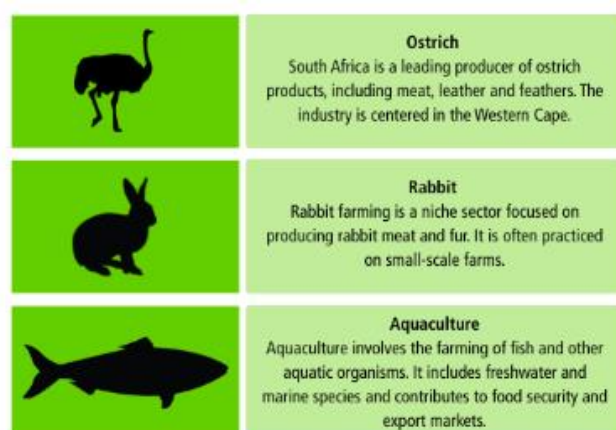


Figure 4.7 *Classification of other livestock sectors*

Source: DALRRD (2024b)

4.2.3 Communal livestock farming

Communal livestock farming involves (ARC 2024):

- 1. Capacity building**
Providing training and support to communal farmers to adopt CSRA practices.
- 2. Access to resources**
Ensuring access to resources such as infrastructure, water, feed and veterinary services.
- 3. Community engagement**
Engaging local communities in the adoption of sustainable practices and creating awareness about climate change impacts.

According to the Bureau for Food and Agricultural Policy, the smallholder sector held 40% of the 13 million cattle herd in SA for the year 2020, of which 5.2 million was in the hands of communal farmers (NAMC 2017). Estimated livestock numbers for 2020 are found in Table 4.2.

Table 4.2 *Estimated livestock numbers in 2020 (millions)*

	Eastern Cape	Free State	Gauteng	KwaZulu- Natal	Limpopo	Mpumalanga	North West	Northern Cape	Western Cape	TOTAL
BEEF CATTLE										
Commercial	1 513	1 231	321	1 409	650	860	1 035	603	219	7 868
Communal	1 272	911	245	1 116	433	603	713	208	232	5 733
SHEEP										
Commercial	6 410	4 271	91	676	226	1 534	612	5 361	2 380	21 561
Communal	906	604	13	95	31	217	86	758	336	3 046
MEAT GOATS										
Commercial	643	67	11	227	349	25	202	144	62	1 730
Communal	1 588	165	27	561	861	61	498	355	152	4 268

Sources: NAMC (2017); Geraci (2020); ARC (2024)

Chapter 5 Climate smart regenerative livestock production: Evidence from the field

5.1 Introduction

Climate smart regenerative agriculture (CSRA), in particular conservation or regenerative agriculture (CA/RA), has emerged as an alternative to conventional agriculture because of losses in soil productivity due to soil degradation (e.g. erosion and compaction). CSRA aims to reduce soil degradation through several practices that minimise the alteration of soil composition and structure, and any effects upon natural biodiversity (FAO 2023). CSRA is a way of managing farming systems to achieve improved, sustained productivity, increased profits and food security while preserving and enhancing the environment and the resource base (Smith et al. 2016) (also see Chapter 0 and Annexures 1 and 2 for detailed descriptions).

Regenerative grazing is managed grazing (Annexure 3). The farmer can manage the under-/overgrazing issue and evenly spread herd impact. The idea is to mimic nature whose grasslands evolved in a symbiotic relationship involving four players – ruminants, predators, grasses and the soil microbiome (Meissner et al. 2013b; FAO 2023).

Livestock integration in agricultural systems is also an important principle in CSRA (Annexure 2). By adopting rotational grazing systems, agroforestry practices and holistic management approaches, farmers can harness the synergies between crops and livestock to create resilient and regenerative agricultural systems (FAO 2023) (also see Annexure 3).

5.2 Overview of adoption

Studies from 2014 mentioned that CA/RA is practised on about 125 million hectares around the world, covering approximately 10% of the global arable land surface (Kassam et al. 2014). Later studies indicated that it is now practiced on over 200 million hectares worldwide, accounting for approximately 15% of global arable land (Román-Vázquez et al. 2025). The largest and most rapid expansion is still seen in North and South America, Australia/New Zealand, and some parts of Africa. The estimated annual adoption rate of CA has approximated 7 million hectares per year during the last ten years (Kassam et al. 2014).

In South Africa a study found that CA/RA is applied on 1 607 081 ha comprising 25% of the total area under commercial annual crop-livestock systems in South Africa. CA areas under semi-commercial and smallholder systems occupy 13 556 ha during the 2020/2021 season (Smith 2021).

The adoption estimates within the commercial sector are discussed below (also see Table 5.1). While statistics vary with definitions and survey methodologies, emerging evidence suggests the following indicative ranges within the commercial sector 25–35% of livestock operations have implemented some form of climate smart practice. Within these many progressive operations not only implement baseline climate smart techniques but also integrate more targeted resilience and sustainability actions. Among the climate smart adopters:

1. Conservation grazing

Approximately 40–50% of those already climate smart may be employing targeted conservation grazing practices. This suggests about 10–17.5% of all commercial livestock operations are actively using conservation grazing as part of their climate strategy.

2. Conservation Agriculture practices

When considering the integration of conservation agriculture principles within a livestock context (e.g. reduced tillage in forage production, cover cropping in integrated systems), about 35–45% of climate smart adopters might be using these practices. This roughly translates to 8.75–15.75% of the entire commercial population.

3. Integrated resilience and sustainability

When multiple interventions are combined, such as precision livestock management alongside conservation grazing and CA principles, the estimated share of farmers achieving a robust resilience profile might be in the range of 15–25% of commercial operations.

Note: Given overlaps (many farmers may employ both conservation grazing and CA/RA measures), these numbers are best seen as complementary slices of the broader climate smart pie. The different categories include climate smart practices, resilient and sustainable farming, conservation agriculture and conservation grazing.

Table 5.1 *Visualising the adoption of conservation livestock production summarising the above indicative rates*

Category	Estimated Adoption Rate (of Total Commercial Farms)	Comments
Overall climate smart adoption	25–35%	Encompasses a wide range of climate smart practices.
Among climate smart adopters		
Conservation grazing	40–50% of climate-smart adopters (≈ 10–17.5% overall)	Focuses on rotational/optimised grazing to enhance ecosystem resilience.
Conservation Agriculture practices	35–40% of climate-smart adopters (≈ 8.75–15.75% overall)	Integrates practices like minimal tillage, permanent soil cover and rotations.
Integrated resilience and sustainability	~15–25%	Represents operations combining multiple measures into a robust system.

Sources: The resources and references that informed the synthesised figures in Table 5.1 are: CSIR publications, South African Department of Agriculture, Land Reform and Rural Development, Food and Agriculture Organization, a Climate-Smart Agriculture Source Book, Agricultural Research Council publications, National Red Meat Development Programme and Journal Articles

Note that much of the data comes from a synthesis of multiple studies, reports and expert analyses rather than a single source including the different categories: climate smart practices, resilient and sustainable farming, Conservation Agriculture and Conservation grazing. However, the following resources are among those frequently cited for similar figures and discussions around climate smart, resilient and conservation-oriented livestock production in South Africa.

5.3 Supportive information for the mindset of the South African agricultural sector

A study was done to carry out an in-depth assessment on the circular economy in the food and agricultural sector in South Africa, from a resource perspective. In the current context of resource scarcity, global climate change, environmental degradation and increasing food demand, the circular

economy represents a promising strategy for supporting sustainable, restorative and regenerative agriculture. Based on the assessment of the status of the South African agricultural sector and the main pressures facing the sector, together with a review of expected trends in the sector, including local and international circular economy practices, several circular economy interventions were identified. These interventions may have potential for the local agricultural sector (Figures 5.1 and 5.2) (Okole et al. 2022).

Table 5.2 *Proposed circular economy interventions for the agricultural sector*

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

Source: Okole et al. (2022)

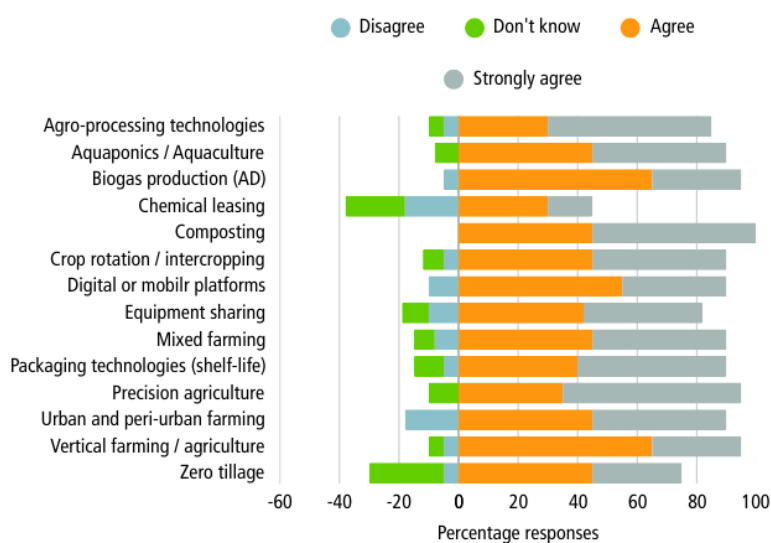


Figure 5.1 *Extent to which circular economy interventions can benefit the agriculture and food sector*
Source: Okole et al. (2022)

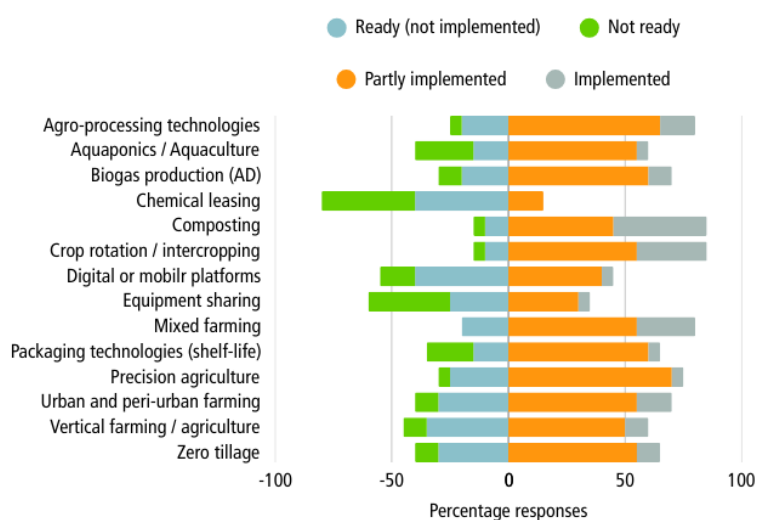


Figure 5.2 *State of readiness and of implementation of circular economy interventions in South Africa*
Source: Okole et al. (2022)

5.4 Case studies about conservation agriculture in South Africa

Case study 1: Bertie Coetzee, Prieska, Northern Cape

(GrainSA 2019)

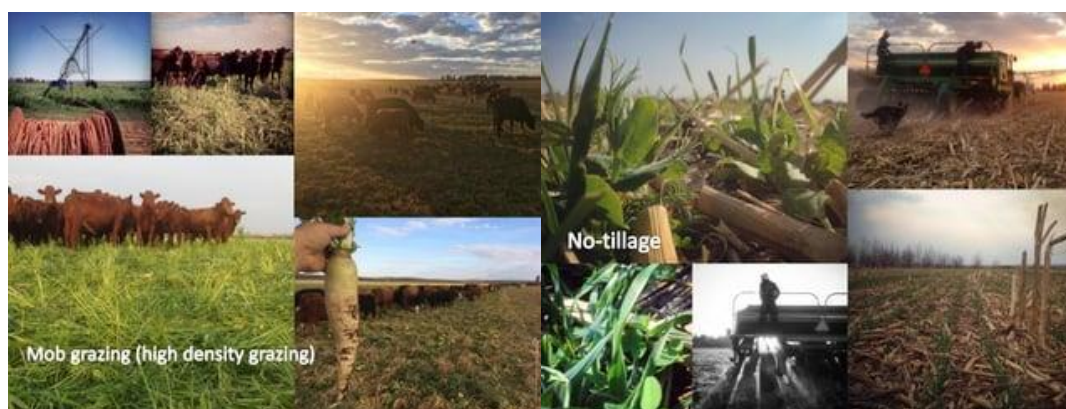
Lowerland is situated in an arid region, farming with diverse annual and perennial crops and livestock, with irrigation from the Orange River. Wheat and maize rotations are planted in a no-tillage system. After seeing improvement in soil conditions with only no-tillage (NT) practices, Bertie gathered knowledge from as many farmers in the country, realising there is more sustainable ways of farming.

By eliminating both chemicals and chemical fertilisers, he started with organic no-tillage systems and CA (wheat-maize rotation). The organic no-till systems have very long rotations with only one or two cash crops in two years' time. In between cover crops are planted and livestock integrated on the croplands by mob-grazing biomass. Practices in these systems include green-planting, rolling-and-crimping, no-till intercropping and relay cropping. Over the years they compare biodiversity and differences between organic-NT vs half-CA vs full-CA cover cropping systems.

The first biggest change was going full no-till on the wheat. Yields decreased noticeably, whereafter they replaced wheat with cover crops and livestock. The second environmental change or adjustment in the system was to improve grazing management on livestock. The benefits hereafter was seen in maize yields after CC and livestock that were better than maize after quick wheat. Several environmental benefits were identified: soil health and structure improved, there were continuous living roots in the soil, and higher soil cover and water infiltration rates. Manure from all livestock and cover crops (leguminous plants to fix nitrogen) served as fertiliser, which means the use of chemicals was reduced and discontinued.

The biggest hurdle on the grain side, was poor yields. Despite setback in grain yields, in the perennials (pecan nuts), yields increased. It was initially difficult to convert from a short-term to a long-term system and to look at the farm as a complete setup rather than individual components. Every day is a learning curve, but experimenting fully on small scale led to success on large scale. Lowerland also had to find new markets outside of Prieska for their non-GMO/organic products.

While livestock integration enhanced financial impacts was experienced, more electricity was needed to irrigate CC, there were pressure on livestock (cattle, sheep, pigs and chickens) to perform a financial function and not just a soil health function. Cattle can easily be moved two/three times per day on pastures with no additional grains (100% pasture fed). Lowerland grazes 200 animals on a 30 ha pivot, moving twice a day with a month of rest before starting over. Sheep are used under the vineyards and pecan nut trees because they cause little to no destruction, and lamb is an easy sell in their market. Pigs receive pumpkins that was not exported. They are used to clean and break pest cycles on all fields, they help plant green mulch by natural plowing actions. The pigs also receive byproducts of the milling operation, then are sold directly to the market.



Lowerland has approximately 120 hectares of organic fields. It takes three years to convert a CA field to a certified organic field, the above practice is the best way to build soils while still generating income with livestock. Fusion of agroforestry and permaculture was another project at Lowerland, where a very high intensity food forest was created on contours: pecan orchids, apple trees, vineyards and date trees were planted together. In between contours high-income vegetable crops were planted. The goal of the project was to see how much income can be generated per hectare.

Case study 2: Ben and DF Fyfer, Vryburg, North West province

One of the most important departure points of CA is the realisation that healthy veld does not start and end with good grass cover, but that the health of the soil is equally important. Moreover, healthy soil and cattle are interconnected. The aim on the farm is to increase the veld's carrying capacity and adding value to their products. Bhetjane Cattle Co practice CA grazing methods – diverse, extensive livestock and grazing systems – with cattle and chicken. The objective of their UHDG system is to create smaller camps to be utilised by ultra-high stock rates for short periods of time. Fyfer started with an UHDG cattle system. After grazing, each camp is allowed to rest for a long period. Cattle introduced to UHDG lost body condition and had poorer performance, therefore the need for a certain type of adapted animal grew. Genetics was a major solution to the challenge of maintaining BCS of animals in such systems. The process of breeding their own breed is described below. Fyfer also realised that farming entailed the entire ecosystem, not just cattle and that an integrated system had financial and environmental benefits. He decided to include chickens in his system, and have these feed on the same veld as the cattle. The chickens are kept in moveable chicken coops which are moved regularly, allowing the chickens to contribute to improving the veld by spreading their own, as well as the cattle's, manure and by combating pests. Fyfer also farm with bees and planted pollination strips near watering points. The bees help to pollinate all the plants in the ecosystem. In their area, cattle farmers typically work with one large stock unit (LSU) per 7–10 hectares. Fyfer has achieved stocking rates of 1 LSU per 2–2.85 hectares.

In 1987, Ben Fyfer, the father of DF Fyfer, of the Bhejane Cattle Company, started using the principles of only using cows in his herd for bull rearing that calved at 24 and 36 months. DF shifted his focus from production per animal to profit per hectare and subsequently changed his production system by deregistering his stud, moving to UHDG and started to breed a composite that fitted in with his management, and environmental goals. To ensure that the final animals had 75% African blood and 25% Beefmaster blood, DF used four breeds as the basis of his composite:

1. Nguni x Boran
2. Beefmaster x Mashona

This animal is a highly functional animal with the various benefits of all the different breeds for the specific needs of the African veld.



This composite is named the Adaptor as his focus is to breed a veld adapted animal that is early maturing, fertile, tick and heat resistant, has good carcass qualities and can fatten on grass only. He breeds this composite specifically to suit his low input ultra-high-density grazing, where through the non-selective utilisation of all the grass, coupled with an adequate rest period, his soil biology will

improve. This in turn will increase grass production and aid him in his goal of maximum sustainable profit per hectare.

Case study 3: Gerrit Van Zyl, Dewetsdorp, Free State

Hanzyl Bonsmara's have been breeding fertile, well-adapted and economically efficient cattle for 27 years. Mr Gerrit van Zyl has been running a stud Bonsmara herd over the last 28 years. The last eight years he adopted a CA farming approach with the main aim of ecological health in mind. The legacy Gerrit aim for is to leave the planet a better place and to teach as many agriculturists, as possible, to respect the planet and to improve soil health while farming in a sustained manner.

Van Zyl has, over the years, improved the fertility of his herd by applying the principles of only using bulls where the mother calved at 24 and 36 months. It is fascinating that by doing this he has consistently bred mother animals that can produce a calf from the age of 24 months. Gerrit also started changing his grazing management to an HDG system, where cattle are moved every one to three days. As a result – and financial and environmental benefit – this has doubled his stocking rate per hectare, from 1 LSU per 6 hectares to 1 LSU per 2–3 hectares. The infrastructure cost Van Zyl only 15% of the cost to buy a new farm to support the same amount of animals when considering a 1 LSU to 6 hectares stocking rate. When changing over to UHDG, you must consider what effect the lower conception will have on your cash flow. If managed incorrectly, UHDG is one of the easiest ways to lose money and increase financial costs. If managed correctly, it is the only way to increase profits, through increasing the stocking rate. You must work with a system. There is no one size fits all approach, neither is there a silver bullet that corrects every wrong management decision. You can change between the various grazing management systems. This depends on the nutritional needs of your mother animals and your veld conditions as well as the use of cover crops or harvest rests. All this must also be incorporated into your management system.



Van Zyl always re-emphasise the fact that it is not about what breed must be used, but rather what type of animal must be used to fit an UHDG system. The mother animal must be a grass-efficient animal. Ideally, with a huge rumen capacity, that can give you a calf from 24 months and every year after that. And wean a calf of 42–50% of her body weight.

Case study 4: Hendrik O'Neill, Solomon Munyenga, Sally Nicholl and Anderson Mutasa

The partners did not have land or lots of money, so they decided to form a partnership with the aim of farming simply, on a small scale. They farm near Bela-Bela in Limpopo.

They leased 40 hectares of degraded ground near Hammanskraal, in the Limpopo province. The plot was a typical example of desertification with very little ground cover because of overgrazing by livestock. Alan Savory's TED Talk on fighting desertification – through *holistic management and planning grazing* – inspired them. They started with nine pigs on a 20 ha plot, grazing intensively for not more than 24 hours in a small, UHD movable, electric wire fenced camp. This UHD system mimics the behaviour of herds of migratory wildlife. Each day, a new area of soil was snouted, trampled and fertilised. The thick layer of grass and organic matter left behind by the pigs helped retain moisture. It was not long before the soil's capacity had improved so much that there was thick, healthy grass growing – despite the drought they experienced enormous environmental benefits. They have quickly built up a herd of 500 free-range pigs that are moved approximately every one to three days, as that is when they have churned up the whole area. Special structures have been built for young growing pigs. Either trees for natural shade, or mobile shade huts are provided in the camps. The pigs do not have farrowing pens as they make their own beds under trees using grass. The mothers are kept in separate paddocks until the piglets are big enough to join the main herd. Cattle and chickens were introduced into the system. Cattle are moved four times per day and the chickens every day. Six weeks pass before the pastures is grazed again. After two years of using this system, they had 40 healthy hectares supporting 1 000 pigs, 20 cattle and 800 free-range chickens. The animals work and fertilise the soil so well that vegetables can be planted immediately after animals move to the next camp.



No inherited land, no big loans, no expensive equipment, no cycle of factory farming, no high turnover or low job satisfaction, just good land management. The farm supplies organic, free-range meat to a rapidly growing niche market, and provides enough meat, eggs, milk and vegetables to support the partners and their families. That is seen as true wealth and truly a long-lasting social benefit.

Case study 5: Hannes Botha, Carolina, Mpumalanga

Botha has achieved higher profitability by introducing CA farming practices on his farm, Fairview. The carrying capacity on the farm doubled in a single season as CA grazing practices intensified. A few

years prior to this journey towards restoration, Botha had tried to implement precision farming which increased financial cost tremendously, but had brought very little improvement to his operation. He began researching alternative farming techniques and started learning from CA farming pioneers. He found that conventional agricultural practices had a negative impact on the environment and people. He moved away from conventional agricultural farming practices when realising it does not make sense to spend more and more for the same or smaller profit, and that higher yields do not necessarily equate to higher profits. By implementing the knowledge and using the tools he already had, he changed his livestock management programme to an UHDG system and, within a single season, was able to double the veld's carrying capacity, experiencing both environmental and financial benefits.

Case study 6: Danie Slabbert, Reitz, Free State

Slabbert runs about 500 head of Drakensberg cattle on his farm and started using a UHDG system in December 2017. During summer, the animals are moved hourly between 6am and 7pm, which equated to an average animal density of about 5 000 LSU/ha/hour, extrapolated to a carrying capacity of 6 LSU/ha/year. (The official government recommendation for this farm is 4 LSU/ha/year.) UHDG leads to non-selective grazing, a high degree of trampling and a high concentration of manure and urine. The same system is used during winter, but the animals are moved to graze on maize and soya bean residue and cover crops specifically planted for them. The sandy and loam soils these animals are grazing on are the farm's marginal lands. The better soils are used for crop production.

To track the progress, monitoring points in the area include four on the main farm, where the UHDG (or non-selective grazing) was taking place, two on a neighbouring farm, where animals were moved between the two camps on roughly a monthly basis. This grazing approach led to a high degree of selective grazing, and the sites were collectively known as the "selective grazing control sites". The third site was a portion of veld where no grazing took place. The grass species composition/diversity was determined, also ecological status groups, veld condition score percentage and grazing capacity. Finally, the biomass production (kg/ha) was also an important factor to look at during this study. Frits's study, *The impact of non-selective-grazing on rangeland ecology*, recorded the following changes over five years at Danie's farm: 50% increase in palatable grass species, 80% increase in indigenous legumes, 64% increase in biomass, 60% increase in botanical diversity, two times the water infiltration rate.

Starting with the land itself, Slabbert moved away from chemicals and conventional grain and livestock farming methods to regenerate the veld, soil and vegetation. Many years later, Sewe Slabberts are today a fully integrated CA crop-livestock farm where cattle, sheep and chickens are now used to support the soil's natural regeneration while experiencing growing financial and environmental benefits.



Case study 7: Danie Bester, Balfour, Mpumalanga

Bester focuses on maize and soya bean production, and plants cover crops between rotations. Instead of dousing the fields with pesticides, installing irrigation systems and churning the earth with heavy tillers, Bester grows cover crops during the off season. Firstly, each cover crop provides a solution to a specific problem in the soil. Secondly, it provides fodder for livestock. Cattle graze on the plants, dropping manure as added fertiliser. Bester identified many environmental and financial benefits: with livestock in the system, micro-organisms in the soil need not only depend on decomposing plant matter for survival; they can also feed on dung and urine to grow and complete their life cycle. The grazing action also stimulates plant growth, which improves the stocking rate. Ruminants can vastly increase the amount and variety of nutrients available to soil microbes, because their digestive systems break down plant matter through both fermentation (performed by gut microbes) and digestion (performed by enzymes). Another result is increased earthworms that oxygenate soil, while the untilled, shaded soil retains moisture and nutrients, and weeds are kept under control. His technique remains rare in South Africa, which has the most industrialised farms on the continent. Most use large-scale monoculture farming reliant on chemical fertilisers and pesticides. But in addition to being climate smart, Bester's maize and soya yields are among the highest in the country. Bester's fields are rich without artificial watering. He pulls out a stalk, revealing a bit of fungal growth and a wriggling earthworm – creatures not found on farms doused with pesticides, he said. South Africa's climate is warming twice as fast as the rest of the world, according to experts, meaning changes to farming are crucial.

Case study 8: Magnus Theunissen, CA farmer, Ottosdal, North West

Magnus experiments with interseeding which enables him to run two farming operations on the same hectares. Plantings are carefully managed so that cash crops suppress the growth of the cover crops during the growing season. Once the cash crops are harvested, cover crop growth accelerates markedly, and livestock grazing can commence virtually immediately. His average maize yield for the season was a measly 880 kg/ha, compared to his usual average of 5 t/ha. However, the interseeded trial plots yielded 2.4 to 2.8 t/ha compared to 600 kg/ha on the monocropped land. In sunflower trials, intercropped fields with bio-stimulants yielded 1.6 to 2.5 t/ha, compared to 700 kg/ha monocropped.

He has been running minimum-till trials on his farm for eight years, and added cover crops and livestock for the past four planting seasons. In the CA trials with livestock integration on his farm, cattle high density grazes on the trials, but also overnight on the fields to get the most out of microbe transfer from the cattle to the soil. According to Theunissen, animals have been created in a certain way to graze in a certain way, and we must stop working against nature. The actions of the manure, urine and spit of the animals all make a difference on the environment.

Case study 9: Zunckel family, Bergville (KZN) and Warden, Free State

The Zunckels' 2 150 ha farm, Rustenburg, irrigated winter wheat on about 120 ha in rotation with both irrigated and dryland summer crops, typically comprising two-thirds yellow maize and one-third soya bean. They buy weaner calves of approximately 220 kg in KwaZulu-Natal to utilise the cover crops from April onwards. With the help of a good lick, they gain approximately 200 kg during winter. In normal years, they sell approximately 80% of them directly from the oats grazing. They send the rest to the feedlot until they are ready to be marketed. Egon Zunckel has been practicing no-till and minimum-tillage farming for 36 years and incorporating cover crops for the past nine years. Zunckel farm introduced diversified crop rotation, and cover crops which now form part of their permanent rotation. By practicing NT and cover crops, a field covered with oats produced double the yield (15.8 tonnes/ha compared to 7 tonnes/ha before). The following crop rotation was implemented: white oats were planted first, followed by no-tilled soybeans on top of the oat residues after being grazed by cattle. Wheat was then planted after the soybeans, resulting in their best wheat crop ever, yielding about 8 tonnes/ha. Subsequently, maize was no-tilled into the wheat stubble, and in the same field 15.8 tonnes/ha under irrigation. For 12 years, the Zunckel farm operated without cattle. However, with the introduction of cover crop mixtures, cattle were reintroduced into the system. The combination of cover crops and the NT system improved soil health while simultaneously providing feed for the cattle. They achieve maximum soil cover via either living plants or plant residues, and always have a living root system in the soil. Cover crops play a pivotal role in combating nematodes, and help to improve overall soil health. Cattle also graze on the cover crops and maize residue. Their practices have also helped to reduce soil erosion, improve water infiltration and increase moisture retention, which has led to sustainable production and higher yields over time. Zunckel Farms' philosophy is that a healthy agricultural system is one that supports all forms of life, and one of the pillars of its operations is the restoration of carbon and organic matter in the soil.

Case study 10: Department of Agronomy at Stellenbosch

Prof Pieter Swanepoel, head of the department, says that livestock serves as a form of mechanical and biological weed control and complements no-tillage (NT). "Using NT and livestock in crop rotation effectively reduces the weed seedbank while improving soil health compared to monoculture tillage systems. Our findings suggest that both NT and livestock foster a more balanced species composition of weeds, while the abundance of weeds (i.e. weed pressure) is much lower. Despite the challenges posed by herbicide resistance, our studies support the idea that producers should adopt NT and integrate livestock to manage weeds while enhancing soil quality."

The obvious advantage of livestock in a CA system is the diversified income streams. In the Western Cape, the popular Dohne Merino diversifies a grain producer into meat and wool income streams, even if livestock generally comprises a far smaller proportion of farming enterprises than grains. In the eight crop rotation systems at Langgewens, the four with livestock are the most profitable. Smit believes this is due to a combination of beneficial effects associated with grazing and the fact that wheat plantings in these systems always follow a legume crop, which adds nitrogen to the soil. Wheat produced in the systems that incorporate livestock also had higher protein content than wheat from systems without livestock.



Case study 11: Challenges and opportunities for climate smart beef production under climate change in southern Africa

The direct effects of climate change are mostly associated with heat and the indirect effects with feed sources, ecosystem changes and diseases. Research and innovations by Scholtz et al. (2023) had useful discoveries on climate smart beef production in southern Africa. Studies found that the utilisation of adapted and indigenous genotypes and the development of early warning systems can result in maintained levels of production despite adverse weather conditions. Improved efficiency of production will have positive effects on sustainability and can serve as a mitigation strategy. The focus must be to improve cow-calf efficiency, selection for alternative measures of efficiency, as well as the effective use of crossbreeding. Residual traits should be used when selecting for efficiency. Also, effective crossbreeding can have a small to medium effect on the reduction of the carbon footprint, while increasing the efficiency of production

Case study 12: The effect of climate change on livestock production with emphasis on specific disease vectors and alternative control measures

Climate change will have several effects on livestock production and more so on extensive livestock production associated with South African conditions. Disease prevalence and the existence and spread of vectors associated with vector-borne disease will also undergo drastic changes for the negative. Several vectors, especially ticks have already built up some resistance to currently available compounds used in acaricides. A study done by Rust and Rust (2012) looked at the development and use of a concealed antigen vaccine for the control of a variety of ticks in cattle. Results indicated a positive response to the use of the vaccine that reduced the use of acaricide to the minimum. However, spot treatment of ticks in certain strategic body regions of cattle will still have to be

incorporated for total effective control. The frequency of vaccinations is in the region of four months during peak infestation periods and can be used as both a preventative and treatment regime.

Case study 13: The adoption of climate smart regenerative agricultural practices in livestock production systems

Communal livestock producers are highly vulnerable to climate change and are unpleasantly affected to varying extents through southern Africa and mostly in semi-arid areas. Climate variability and change affect seasonal pasture production and lessen feed quality and quantity, and adaptation strategies are recommended for livestock productivity and profitability. Adoption and application of daily and seasonal weather forecasting and long-term climate predictions coupled with climate-smart technologies for land-based grazing communities have a greater potential of enhancing pasture and livestock production. A study done by Zuma-Netshiukhwi et al. (2023) stated that climate change adaptation strategies involve a grazing management approach through rotational grazing and keeping to livestock units, different animal type selection and breeding strategies, fodder cultivation as supplementary feed and the use of early warning systems which provides farmers with climate predictions for proper planning and decision making.

Case study 14: Skimmelkrans dairy farm, Mossel Bay

The Skimmelkrans dairy farm, located near George, in the Western Cape, is the group's pilot project for low-carbon emissions, following the announcement in 2020 to pursue a net-zero project there. Results to date from the Skimmelkrans Dairy pilot project include annual averages of 500 tons of manure processed, 14.5 million litres of water recycled and 6 000 tons of carbon sequestered through soil work. The project harnesses cutting-edge techniques such as biological pest control and zero tillage, which minimises chemical use, improves soil health and boosts crop yields. Over and above these, a solar installation generates 285 kVA of power.

A fourth-generation establishment, the family farm is run by farmer George Kuyler and his relatives. During a comprehensive farm tour in 2024, Kuyler highlighted that it employs 36 people daily throughout the year. The impact of this employment, when expanded, indirectly benefits about 360 people. Skimmelkrans boasts a pasture-based herd of over 1 000 cows. Adult female cows are artificially inseminated with sperm procured globally, ensuring optimal pregnancy metrics. Technology monitors the cows' health, ensuring optimum and safe production. Nestlé further uses this traceability when receiving the milk to ensure product uniformity. Milk production at the farm is seasonal, with the farm currently supplying about 13 000 litres daily. The cows are milked twice daily, using a rotating feeder and milking system that prevents contamination by ensuring milk is not touched by human hands. The farm implements regenerative agriculture systems, displacing emissions generated at the farms by removing the same amount from the atmosphere through soil work, water conservation, feed management and manure processing. The factory implements sustainability initiatives, including a water recovery system that captures and treats evaporated water from milk processing for use within the facility, reducing municipal water intake. A wastewater treatment plant treats process water for irrigation and truck washing. The factory also uses digital monitoring and predictive maintenance systems for more sustainable manufacturing practices and is continuing to explore AI

integration. Kuyler said that the switch to regenerative agriculture has transformed their farm. Not only are they seeing better yields, but they are also contributing to a healthier environment.



Case study 15: Increasing East African Dairy Productivity and Reducing Emissions Intensity: Co-Investments in Early Forage Market Development

The Nourishing Prosperity Alliance is a project led by Land O'Lakes Venture37 with Forage Genetics International, Corteva Agriscience, and the International Livestock Research Institute. A pilot of the project took place in Kenya from 2020–2023 and aimed to provide a scalable, market-wide solution to key gaps in the animal nutrition market to improve dairy production, boost climate resilience among farmers, increase access to animal-sourced foods, and reduce emissions by promoting climate-smart agriculture and optimised animal nutrition practices. The pilot strengthened forage enterprises, feed processors, and sales agents to increase access to nutritious and climate-adapted forage for dairy farmers and educate farmers on improved cow nutrition and ration balancing. The pilot reached 7 408 Kenyan farmers (60% women) and 25 private sector actors and produced the following results:

- 26% estimated GHG emissions intensity reduction for milk produced
- 46% average increase per smallholder farmer of total litres of milk produced annually
- 41% average increase per farmer of total litres of milk produced annually for emerging farmers
- 68% average increase per farmer in annual income from milk for smallholder farmers
- 34% average increase per farmer in annual income from milk for emerging farmers

See also case studies in Chapter 2: Michael Mandy, Izak Dreyer and Kurt Heward, Cassia County in Idaho, about livestock integration in grain systems.

Chapter 6 The cost and benefits of CSRA within livestock production

6.1 Introduction

Maree et al. (2025), after conducting a thorough review of many global case studies pertaining to the impact of various grazing management systems summarised the results as illustrated in Figure 6.1 and Table 6.1. The general benefits noted with respect to adaptive grazing (i.e. grazing methods that embraces one or other facet of CSRA within extensive livestock production systems) includes increases in soil organic carbon, soil fertility, more standing biomass, improved nutrient cycling, a reduction in soil erosion, etc.

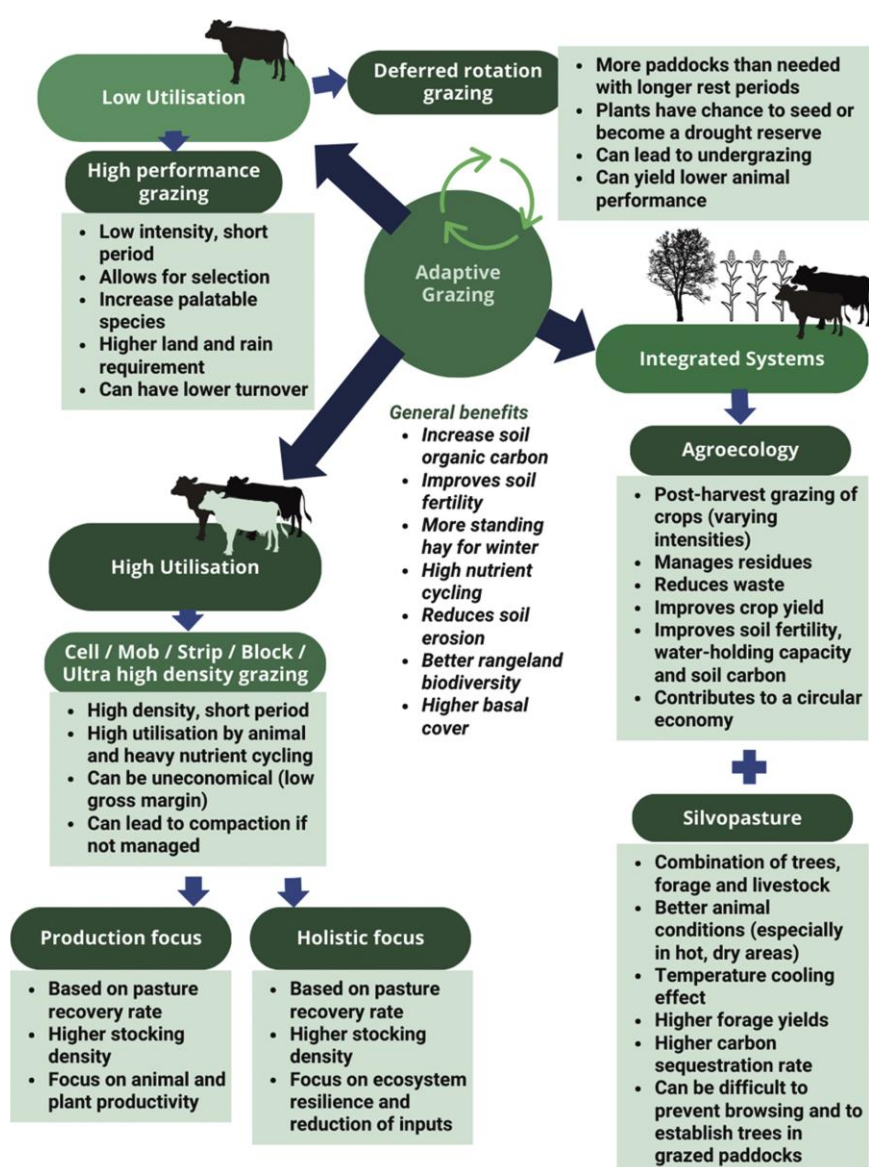


Figure 6.1 Cost and benefits of adaptive grazing

Source: Maree et al. (2025)

Table 6.1 *Cost and benefits of various grazing systems: Results from a global survey*

Area	System	Responses
New Zealand A) Waikato; B) Canterbury	Adaptive grazing (dairy)	NECB of $12 \pm 30 \text{ g C m}^{-2} \text{ y}^{-1}$, NEP: $283 \pm 31 \text{ g C m}^{-2} \text{ y}^{-1}$ Increased diversity led to carbon neutrality or carbon sources
	Crop>pasture transitions	Net carbon loss (higher in longer phases) Larger C losses in allophanic, gley and organic soils
	Supplemental feed crops	Reduced NECB to $-32 \pm 41 \text{ g C m}^{-2} \text{ y}^{-1}$
USA A) Texas	Adaptive grazing	Soil respiration changed from 35.3 to 64.6 mg CO ₂ /kg soil and WEOC from 187.2 to 232.2 mg/kg Higher forage production (+1 500 kg/ha) Lower cost (\$37 050) and revenue (\$38 548) Higher standing forage 20% higher daily liver weight gain
	Continuous grazing	Higher winter crude protein and digestible organic matter Higher cost (\$48 971) and revenue (\$42 897)
United Kingdom A) Various B) Rothamstead research centre	Zero grazing	Declines in diversity for soil organisms and plants, No difference in bacterial diversity Nematode, mite and springtail diversity increased by 15%, 5% and 15%, respectively
	Adaptive grazing	SOC increased 1.24 t C/ha/year Higher pasture growth (39–54%), better sward composition and animal production Reduced greenhouse gas emissions Liveweight of 483-890 kg LW/ha
	Continuous grazing	Decrease of soil carbon by 0.45 t C/ha/year Liveweight of 367-585 kg LW/ha Less efficient carbon sequestration and higher impacts
Northern Ireland, Londonderry	Grassland transition to woodland/silvopasture	+ SOC by 11% and 47% (depending on depth of measure of 0– 15cm or 15–30cm)
	Woodland transition to grassland	Decreased SOC
Ireland A) Dowth research farm B) Loughhall	A) Adaptive grazing (multispecies swards and woodlands)	A) Nitrogen use reduced by 65%, ADG improved 20%, increased earthworm population by 300%; Water infiltration rate improved 14-fold; GHG emissions per kg of meat reduced by 26%, with 53% reduction in wheat production emissions. Some farms achieved net zero 97% of total carbon was stored in soil.
	B) Silvopasture (compared with traditional grasslands)	B) Improved tree growth, increased soil carbon, extended grazing season of 17 weeks, improved soil infiltration vs regular grasslands; Farm emissions were offset by 3.3%. 77.28 t C/ha stored over 21 years
USA, California	Crop-livestock systems	No differences in physical soil properties Higher microbial, bacterial, fungal and actinomycete content in soil Higher microbial biomass carbon at depths of 0–15 cm, 15–30 cm and 30–45 cm, decreasing in effect per layer. Increased soil organic carbon at 15–30 cm and 30–45 cm (+3.5 g/kg and + 2.1 g/kg)
South Africa, North-East Free State	Adaptive grazing	Decreaser grasses increased by 1.2%, indicating improvement in veld condition. Increaser grasses decreased by 1.8%, showing reduced disturbance and overgrazing effects; VCS increased by 7.9%; Biomass production is 5 212 kg/ha. Grazing capacity is 2.7 ha/LSU; Grass species diversity increased by 6 species, indicating better biodiversity

	Continuous grazing	Presence of decreaser grasses at 15%; Increaser grasses decreased by 38.7%, still high due to selective grazing management; VCS decreased by 10%; Biomass production is moderate at 3 153 kg/ha; Grazing capacity 5 ha/LSU; Grass species diversity remained constant at 11 species, indicating stable but lower biodiversity
	No grazing	Decreaser grasses decreased by 13.2 = a complete loss of palatable species; Increaser grasses increased by 20.1%, indicating undergrazing and accumulation of unpalatable species; VCS decreased by 6.3%, Biomass production is 6 760 kg/ha but includes a high proportion of moribund material; Grazing capacity is 3 ha/LSU, likely overestimated due to high volume of low-quality biomass; Grass species diversity decreased by 8 species, indicating a loss of biodiversity

Source: Maree et al. (2025)

Notes: NECB, net ecosystem carbon balance; NEP, Net ecosystem production; SOC, Soil organic carbon; VCS, veld condition score

Table 6.2 *Summary of CSRA practices and technologies for land-based systems, their impact on food security, climate change adaptation and mitigation, and the main constraints to their adoption*

	Impact on food security	Effectiveness of climate change adaptation practices and technologies	Effectiveness of climate change mitigation practices and technologies	Main constraints to adoption
Grazing management	+/-	+	++	lack of technical information and capacities, especially in extensive systems
Pasture management	+		++	technical and economic in extensive systems
Animal breeding	+	++	++	technical, economic, institutional: especially in developing countries
Animal and herd management	+	++	+	technical, institutional: especially in developing countries
Animal disease and health	++	++	+	technical, institutional: especially in developing countries
Supplementary feeding	+	+	++	easy to implement, but costly
Vaccines against <i>rumen archaea</i>	++		+	not immediately available, may have low acceptability in some countries
Warning systems	++	+		technical, institutional: especially in developing countries
Weather-indexed insurance		+		technical, economic, institutional: especially in developing countries
Agroforestry practices	++	++	++	technical and economic

- = low; + = medium; ++ = high

Source: FAO (2006)

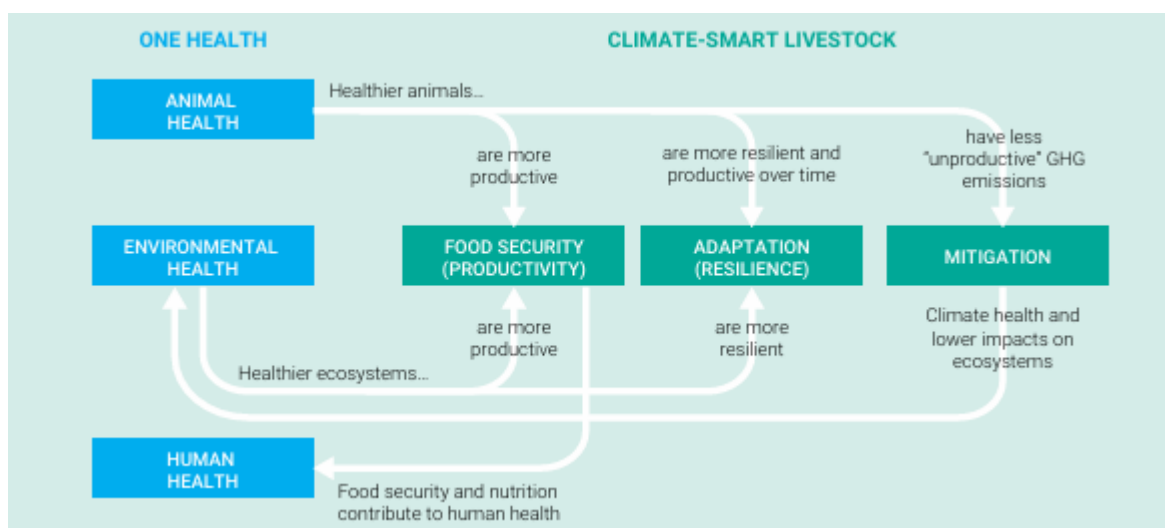


Figure 6.2 Methodological elements for the assessment of climate smart livestock performance

Source: The World Bank (2025)

Note: One Health is an integrated, unifying approach that aims to sustainably balance and optimise the health of people, plants, animals and ecosystems. The Food and Agricultural Organization of the United Nations promotes a One Health approach as part of agrifood system transformation for the health of people, animals, plants and the environment.

6.2 Environmental

Agricultural land covers about 80% of South Africa's total land area. Of that agricultural land, 12% is classed as arable, with major crops including sugar cane, maize, wheat, soya beans, apples, grapes, apricots, avocados and citrus. Additionally, large tracts are used as permanent pastureland for livestock farming, including chickens, sheep, cattle, goats and pigs. Millions of hectares of land are subject to extreme weather events, low production outputs, marginal markets and poor adaptive capacity. Conventional grazing management and intensive farming practices have depleted the soil, with 33% of South Africa's grasslands already severely degraded. Feedlots have a significant impact on the environment, as they take nature's fertiliser (cattle manure) and turn it into a waste product, poisoning water sources and the atmosphere. Secondly, unlike grass finished beef, they are not part of a natural ruminant carbon cycle that draws carbon out the atmosphere and cycles it into the soil. Climate smart grazing management have restored many degraded grasslands and natural pastures throughout South Africa (Meissner et al. 2013a; Smith et al. 2022; Johnston et al. 2024).

Rangeland condition and grazing capacity may deteriorate because of environmental conditions and further invasion by alien vegetation, but mostly because of overutilisation of the resource. The consequences are shown in Table 6.3. Between the 1960s and early 1990s degradation of the natural vegetation, loss of underlying soils, poor water retention because of wetland drainage or damage, alien plant invasion and bush encroachment have been reported by local scientists as reasons that rangeland condition has deteriorated and ecosystem resilience has been damaged (DAFF 2006).

Table 6.3 Rangeland condition and gross margins as influenced by grazing capacity

Grazing capacity (ha/SSU ^(a))	Rangeland condition	Rangeland productivity (%)	Gross margin (R ^(b) /ha)	Effective rain (cents ^(c) /mm)
3.23	Good	100	104	20
1.39	Moderate	62	48	10
0.87	Poor	30	28	5

(a) SSU: Small Stock Unit; (b) South African rand; (c) South African cents.

Source: Fouché (2010)

Benefits

- CSRA practices in livestock management improve rangeland condition and grazing capacities of natural pastures.
- Improved plant cover and species composition also support an increase in rangeland biomass. Where livestock is integrated in horticultural and grain systems, CSRA practices such as no-till farming and cover cropping, enhance soil structure, increase organic matter and improve water retention.
- Reduced tillage, cover crops and soil coverage help conserve soil moisture, leading to better water use efficiency, and minimise soil erosion.
- Diverse crop rotations, cover crops and grass species increase in rangelands promote biodiversity, which can improve pest control and soil health.
- CSRA contributes to carbon sequestration, reducing greenhouse gas emissions and improving overall ecosystem health (see case study 14 and 15 in Chapter 5).
- Reduced use of synthetic inputs and better soil management practices lead to improved air and water quality (Meissner et al. 2013a; Smith et al. 2022; Moret-Bailly & Muro 2024).

Costs

- Transitioning to new practices may initially disturb the soil and local ecosystems, potentially leading to temporary negative effects. Setting up systems like rotational grazing and enhanced cover cropping often involves building new infrastructure or modifying existing elements.
- Implementing new systems may require additional resources, such as water for establishing cover crops or energy for new infrastructure.
- While regenerative practices can sequester carbon, certain activities like increased use of machinery or inputs during the transition phase may temporarily increase greenhouse gas emissions (Meissner et al. 2013a; Smith et al. 2022; Moret-Bailly & Muro 2024).

6.3 Financial

Benefits

- CSRA livestock production practices can lead to cost savings through reduced use of supplements and medicines, and reduced use of synthetic fertilisers, pesticides and herbicides in natural veld, croplands and horticultural systems.
- Improved soil health and water retention due to integrated livestock systems can lead to higher crop yields and better forage quality for livestock (see case study 15 in Chapter 5).
- Products from these systems may attract premium prices in markets that value sustainability and environmental stewardship. Over time, CSRA can lead to more stable and resilient farming systems, reducing financial risks associated with climate variability and market fluctuations (Meissner et al. 2013a, b; Smith et al. 2022; Maluleke et al. 2024; Moret-Bailly & Muro 2024).

In Figure 6.3 Farmers 1 and 2 are regenerative farmers applying a range of climate smart adaptive grazing management strategies in different agro-ecological zones of South Africa. Their financial returns outweigh that of the South African average by several times over both in terms of profit as well as production.

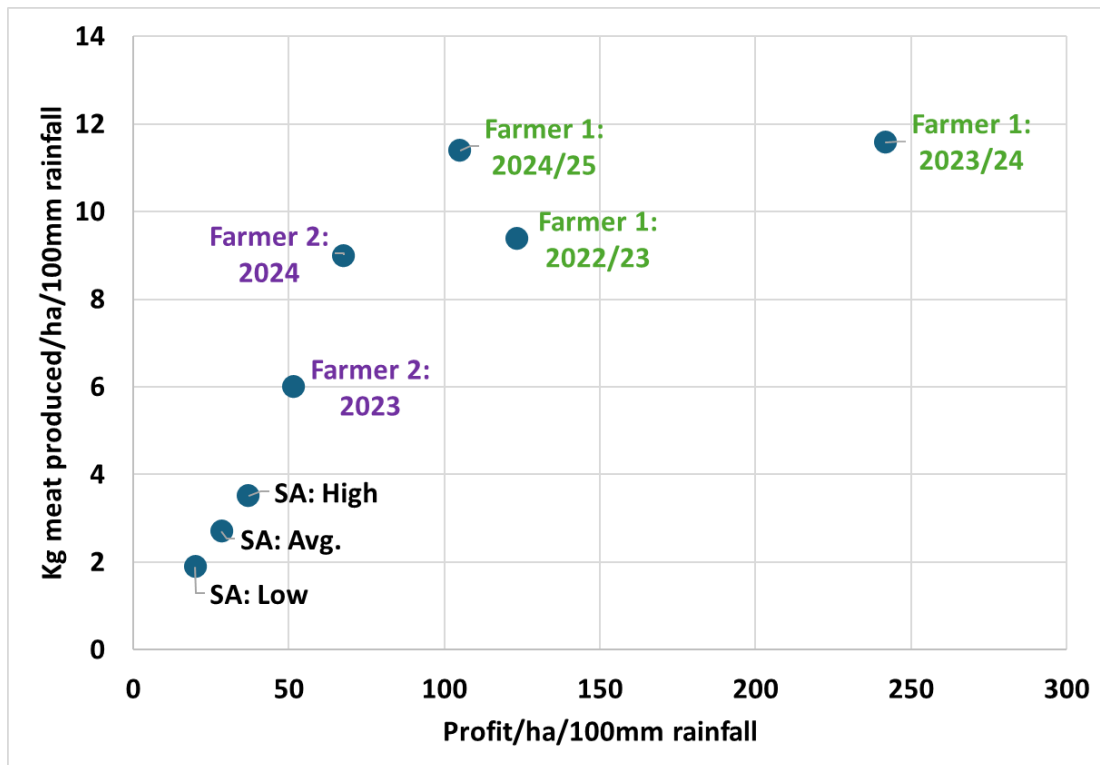


Figure 6.3 Comparative analysis in profitability and production between two regenerative farmers and the South African average

Source: Own analysis of farm data

Costs

- Transitioning to CSRA practices may require initial investments in equipment, such as no-till drills, cover crop seeds, water infrastructures and fencing for rotational grazing.
- Farmers may need time to learn and adapt to new practices and techniques, which can temporarily reduce productivity. CSRA often requires more careful planning and management, including timing of livestock introduction, crop rotation schedules, integrated pest management and weather forecasting and climate prediction instruments or access to such databases.
- While CSRA can reduce labour in the long run, the initial stages may require more labour (Meissner et al. 2013a; Smith et al. 2022; Maluleke et al. 2024; Moret-Bailly & Muro 2024).

6.4 Social

Benefits

- CSRA livestock production often involves community-based approaches, fostering collaboration and knowledge sharing among farmers. By increasing productivity and reducing input costs, CSRA practices can enhance the livelihoods of smallholder farmers. Improved soil health and water conservation lead to more stable and increased food production, contributing to food security (see case study 15 in Chapter 5).

- Reduced use of antibiotics, synthetic chemicals lead to healthier food products and a safer environment for farm workers and communities.
- CSRA practices can empower farmers by providing them with sustainable and resilient farming techniques. Adoption of CSRA often involves education and training programmes, improving farmers' skills and knowledge (Meissner et al. 2013b; Smith et al. 2022; Moret-Bailly & Muro 2024).

Costs

- Farmers may need initial training and education to adopt CSRA practices, which can be time-consuming, require resources and possible mental challenges. Traditional farming practices may be deeply ingrained, and there may be resistance to adopting new methods.
- Some CSRA practices may initially require more labour, which can be a challenge for smallholder farmers with limited resources.
- Access to necessary resources may be limited for some farmers (Choudhary et al. 2022; Moret-Bailly & Muro 2024).

6.5 Reflecting on methane emissions within the livestock sector

Ruminants are grazing herbivores that acquire the nutrients for their sustenance from plant-based food. They do so by, among others, fermenting their feedstock in a specialised stomach prior to digestion. This fermentation process is mainly done by microbes. Because of their unique digestive track, the digestive process of ruminants differs vastly from that of humans or omnivores like dogs. Table 6.4 provides a brief illustration of these differences. Due to this fermentation-based digestive system, ruminants orally release large quantities of methane (CH_4), and CH_4 is a greenhouse gas associated with global warming. This release of CH_4 , also called enteric fermentation, is responsible for between 80% and 90% of all greenhouse gas emissions associated with ruminants.

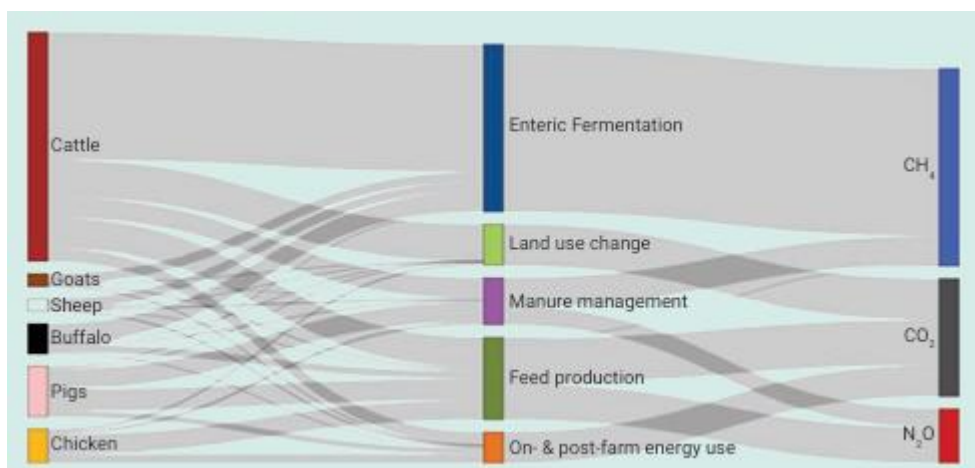


Figure 6.4 *Relative contributions of animal species, emission sources and gases to the total livestock greenhouse gas emissions in the African continent*

Source: The World Bank (2025)

Table 6.4 *Differences in the digestive tracks of humans, dogs and ruminants¹*

	Humans	Dogs	Ruminants/sheep
Empty time of stomach	3 hours	3 hours	Never empties
Inter-digestive rest	Yes	Yes	Never
Bacteria present	Not in stomach, but in gut	Not in stomach, but in gut	Yes, vital, in the rumen (the first stomach)
Digestive efficiency	100%	100%	60% or less
Size of colon	Short & small	Short & small	Long & capacious
Digestive activity of the colon	None	None	Vital function
Bacterial flora in colon	Putrefactive	Putrefactive	Fermentative
Gross food in faeces	Rare	Rare	Large amounts
Feeding habit	Intermittent	Intermittent	Continuous
Survival without stomach	Possible	Possible	Impossible
Length of digestive track to body length	1:5	1:7	1:27

It is enteric fermentation that drives the narrative that domesticated ruminants, notably sheep and cattle, are detrimental for the climate and the environment in general. It is thus suggested that an environmentally conscious person, and society, should therefore reduce the number of sheep and cattle and rely increasingly more on alternative plant-based foods, for example. In the same breath it is often ironically argued for the rewilding of the world. Such rewilding includes non-domesticated ruminants like deer and antelope. While one cannot argue against the grace and beauty of the non-domesticated ruminants, they have the same digestive system than that of cattle and sheep. Thus, are ruminants truly bad for the environment? Are they the curse of nature? A design error of some kind?

Note: On a pure bodymass basis there are fewer mammals (including ruminants) today than ever before in recorded or imputed history, and enteric fermentation is directly linked to body mass.² If the global weight of ruminants is less today than, say, a hundred years ago, why are they so bad for the environment today?

Part of the answer lies with the way conventional carbon accounting is done according to what is called a life cycle analysis (LCA) based on, among others, ISO 14040:2006³ and 14044:2006⁴. According to the LCA, a farm is akin to the production line in a factory, and the interaction of ruminants with a pasture is like that between a motor car and the asphalt road it travels on. This linear approach is largely focused on emissions while placing little emphasis on mitigation and sequestration options.

¹ Adapted from Keith (2009).

² <https://www.science.org/doi/epdf/10.1126/sciadv.abb2313>
<https://www.science.org/doi/epdf/10.1126/science.aao5987>
<https://www.pnas.org/doi/epdf/10.1073/pnas.1711842115>
<https://www.pnas.org/doi/epdf/10.1073/pnas.0801918105>
<https://phys.org/news/2022-10-wildlife-populations-fallen-years-wwf.html>
<https://ourworldindata.org/wild-mammal-decline>
<https://www.worldwildlife.org/press-releases/catastrophic-73-decline-in-the-average-size-of-global-wildlife-populations-in-just-50-years-reveals-a-system-in-peril>
<https://www.nature.com/articles/s41612-023-00349-8>

³ <https://www.iso.org/standard/37456.html>

⁴ <https://www.iso.org/standard/38498.html>

The more recent standard of carbon accounting (ISO 14067:2018⁵), however, outlines a biogenic approach. A biogenic approach, per definition, is a systems-based approach whereby the enteric fermentation of ruminants is weighed relative to their interaction with the pasture or veld, i.e. the local context within which they graze.⁶ The basic accounting identity to capture this interaction is given by the following equation:

The net (sink) or source⁷ =

- Minus CO₂ embedded in the dry matter of the grazed biomass, *plus*
- (The released emissions inclusive of respiration, all greenhouse gasses, and volatilised manure, *less*
- The CO₂ embedded in the litter because of the grazing and fodder sales, *plus*
- The CO₂ embedded in the product, be that milk, wool or livestock sales, *plus*
- The CO₂ embedded in external inputs such as fuel, electricity, pesticides and herbicides).

This identity is derived from the biogenic cycle, which can be described as:

1. As the ruminant grazes and exhales CH₄, it provides the food and energy source for methanotrophs⁸, a soil-based bacteria that uses CH₄ as energy and which converts methane into soil-based sugars, thus reducing the CH₄ load that is emitted into the atmosphere.
2. The remaining CH₄ travels to the top of the troposphere (the atmospheric strata in which we live). This journey takes about 90 days and there they encounter the hydroxyl (HO) radicals.
3. The HO radicals are a group of very short-lived molecules that act as nature's scrubbers. They convert CH₄ and carbon monoxide (CO), among others, into carbon dioxide (CO₂) and H₂O (rain/water).
4. HO reacts faster with CO than with CH₄. The more CO is emitted due to industrial processes and fire, the more it outcompetes the CH₄ – that leaves more CH₄ to be released from the troposphere into the stratosphere, the next atmospheric strata. It is in the stratosphere where CH₄ acts as a greenhouse gas. The CH₄ molecule, however, has a very short lifespan, namely between 7 and 12 years,⁹ before being broken down and returned to the troposphere as CO₂ and H₂O.
5. The returning CO₂ and H₂O, in combinations with sunlight, stimulate plant growth through photosynthesis.
6. It is the plant that is grazed, and notably the carbon within that plant, that is used for herd development, milk production, meat and protein formation, and deposited into the soil in the form of manure and urine. Only a fraction, between 3% and 5%, of the carbon is released back into the troposphere through enteric fermentation, and the cycle starts at #1 again.

⁵ <https://www.iso.org/standard/71206.html>

⁶ <https://www.envirotech-online.com/news/air-monitoring/6/breaking-news/where-do-biogenic-carbons-come-from/56517>

<https://clear.ucdavis.edu/explainers/biogenic-carbon-cycle-and-cattle>

⁷ Please note, sinks are reported as negative values and sources as positive values, hence that the equation starts with a minus and then it counts the releases, fluxes and possible offsetting options back. The carbon embedded in the product (e.g. wool, milk and meat) is indicated separately and not considered part of the sink as they tend not to be permanent, and to avoid double counting.

⁸ <https://en.wikipedia.org/wiki/Methanotroph>

https://link.springer.com/referenceworkentry/10.1007/978-3-319-60053-6_10-1

<https://www.frontiersin.org/journals/microbiology/articles/10.3389/fmicb.2021.678057/full>

⁹ <https://climate.nasa.gov/vital-signs/methane/?intent=121>

Not only is it just a portion of the CH₄ released that end in the stratosphere, but its stay is short-lived; that while the returned CO₂ and water are instrumental in plant and animal growth. These insights, among others, led to the development of an alternative global warming potential measure (GWP*) to that of the conventional GWP. According to the convention GWP measure, CH₄ has a radioactive forcing 27 times that of CO₂, but according to GWP* it is much lower and fluctuates at about 8.¹⁰ The Inter-governmental Panel on Climate Change (IPCC), in their 6th Assessment Report (2023), furthermore distinguishes between GWP, which is an energy-based metric, and global temperature change potential (GTP), a temperature-based metric. GTP is much lower as GWP, namely 4.7 for non-fossil fuel CH₄.¹¹

When considering the carbon sequestration capability of plants and the contribution that responsible herd management can make to accelerate such sequestration, a farm housing ruminants can function as a potential net sink of carbon, cooling the atmosphere. This can be done by applying regenerative practices such as multiple rotations on a single hectare, as is already being practised by forward-looking farmers. For example, a farm of 1 000 ha with two rotations effectively stimulates plant growth and carbon drawdown on 2 000 ha. In the case of irrigated systems, up to ten or more rotations are possible. This expands the annual carbon drawdown area significantly. In addition, such management systems can promote improved water infiltration, biodiversity and enhanced nutrient cycling, among others. It should be noted that the use of rumen supplements as well as careful genetic selection can also help to reduce enteric fermentation.

Grass's life cycle follows one of three possible pathways if not grazed by ruminants. First, it can be burned releasing particulate matter and greenhouse gasses into the atmosphere. It also mostly releases CO which reduce the HO's ability to remove the CH₄, while depleting the soil bacteria. Second, it can be mowed using fossil fuels. This, however, is akin to mining the resource since it removes the nutrients contained therein without replacing it. Third, grass can also become moribund and dry – inert – becoming a sterile system. Often the only way to regenerate such a system is by means of burning or mowing. In all cases, grazing avoids the release of emissions and greenhouse gasses, while promoting soil health and biodiversity and not destroying it.

In summary, photosynthesis stimulates the growth of grass and an increase in carbon drawdown and the deposit thereof in either biomass or the soil – and this entire process is stimulated and accelerated through grazing while avoiding the detrimental consequences of fire and mowing. This systemic and mutually beneficial co-existence of ruminants and grass maintains the functioning of grass-dominant ecosystems. It has done so from the beginning of time. The enteric fermentation further stimulates the methanotrophs while the enzymes in the saliva kick-start the re-growth of plants. In addition, the hoof movement loosens the soil and the nitrogen in the urine and manure stimulates plant growth and soil carbon development. This activates sugars that leads to further root and plant development, resulting in a process whereby ruminants not only can, but do, offset their released emissions. They do so while upcycling low-value and inaccessible starch into high-value, nutritious and accessible protein.

There are many measures that can reduce GHG emissions throughout livestock value chains. Some measures are widely applicable in extensive production systems; some are more specific to the mixed crop livestock system and others are most appropriate in intensive production systems. Because farmers in each production system face different constraints and opportunities, different practices may be more suitable in different contexts. Table 6.5 lists several widely relevant practices, indicating their applicability in different production systems and the likely effects on GHG emissions. Each practice is then discussed in the sections that follow.

¹⁰ <https://www.nature.com/articles/s41612-021-00169-8>

<https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2020.518039/full>

¹¹ https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07.pdf Table 7.15, page 1017.

Table 6.5 *Climate smart livestock practices*

Climate smart practices	Production system	How the practice affects GHG emissions
Forage, feed and water		
• Rangeland management	EXT, CL	Sequesters soil carbon; can improve rangeland forage supply and quality, which could reduce enteric fermentation emissions
• Fodder cultivation and storage	CL, INT	Improves fodder and feed supply and quality which most likely increases productivity and reduces GHG emission intensity, but not absolute GHG emissions Protein content above animals' needs could increase manure management emissions
• Feed purchased fodder or feeds	CL, INT	
• Fodder tree cultivation	EXT, CL	Improves supply of protein-rich fodder, which likely increases productivity and reduces GHG emission intensity of livestock production, and sequesters carbon in trees and soils
• Improved water supply	EXT, CL, INT	For lactating cows, can increase emissions per head but reduce GHG emission intensity if milk yield increases
• Improved feeding practices (e.g. balanced rations)	EXT, CL, INT	Improves diet quality, matching nutrients with animals' needs
Animal and herd management		
• Breeding and animal selection	EXT, CL, INT	Higher yielding breeds may increase GHG emissions but decrease GHG emission intensity; Selection for locally adapted breeds could increase or decrease GHG emissions, depending on breed characteristics
• Improved reproduction	CL, INT	
• Improved animal health	EXT, CL, INT	
Manure management		
• Application to fields	CL, INT	Application to fields daily has the lowest GHG emissions of all manure management options
• Composting	CL, INT	Reduces GHG emissions from manure
• Biogas	CL, INT	Reduces GHG emissions from manure, also has can reduce fuel wood and fertiliser emissions
Marketing		
• Increasing off-take rates	EXT, CL, INT	Reduces GHG emission intensity, can also reduce absolute emissions if animals are sold at younger age
• Preventing waste	EXT, CL, INT	Reduces GHG emission intensity by increasing milk marketed
• Reducing consumption	EXT, CL, INT	Could contribute to lower GHG emissions if herd sizes decrease

Ext = Extensive, CL = mixed crop – livestock, INT = intensive

Source: CCARDESA (2020)

Example of quantification of the mitigation potential of animal health and feed/nutrition interventions

The table below provides an overview of nine FAO studies (click country names to access publications or visit <https://www.fao.org/in-action/enteric-methane/resources/publications/en> to see the list) conducted in various regions and countries to identify and evaluate low-cost strategies to improve productivity while reducing livestock GHG emissions. Country experts and stakeholders were consulted to pre-select potential mitigation interventions. The table focuses on animal health (blue rows) and feed/nutrition (green rows) mitigation interventions and shows their effects on productivity gains ('prod.') and emission intensity reductions ('EI') in the context of the studies.

Interventions	Uruguay	Argentina	Ethiopia	Kenya	Uganda	Tanzania	West Africa*	Bangladesh	Sri Lanka
Vaccination/ control		Tricomoniasis control +21–31% prod. –15–22% EI	Trypanosomosis control –30–31% EI	East Coast Fever vaccination +25% prod. –14–19% EI		East Coast Fever vaccination +12–23% prod. –20–29% EI	Vaccination +15–21% prod. –13–19% EI		
Other				Deworming +12–27% prod. –8–20% EI	Technologies & services +8–40% prod. –2–27% EI			Mastitis prevention +5–14% prod. –3–12% EI	Heat stress management +6% prod. –3–6% EI
Urea-treated crop residues/ straws			–17–44% EI	+20–35% prod. –13–26% EI	+2–4% prod. –1–4% EI	+5–6% prod. –3–8% EI	+26–43% prod. –19–30% EI	+8% prod. –27–36% EI	
Feed supplementation	With legumes (interseeding) –21% EI	With deferred forage +31–65% prod. –23–39% EI	With leguminous shrubs –20–28% EI With UMMB ^b –20–28% EI	With legumes +8–33% prod. –7–25% EI With UMMB –11% EI +13% prod.	With legumes (intercropping) +3–19% prod. –1–12% EI	With legumes (intercropping) +21–38% prod. –12–29% EI	With ration blocks +14–19% –13–19% With legumes +26–35% prod. –21–26%	Balanced feed rations +15% prod. –23–28% EI	With glycidia blocks +102–109% prod. –46–50% EI Balanced ration +48% prod. –20% EI
Feed concentrates	–20–33% EI		–15–43% EI	+4–12% prod. –7–12% EI					+41–47% prod –36–39% EI
Feed conservation		Silage +3–4% prod. –3–5% EI		Silage +8–10% prod. –9–10% EI	+4–21% prod. –3–16% EI		Silage +24–32% prod. –20–24% EI		
Establishment of fodder grasses and legumes	–56% EI	Pasture improvement +7–17% prod. –3–9% EI		+6–25% prod –8–18% EI		+22–44% prod. –13–30% EI	Fodder banks +17–24% prod. –17–23% EI	+4–5% prod. –5–12% EI	

* Benin, Burkina Faso, Mali, Niger, Senegal. ^b Urea-molasses multi-nutrient blocks.

Figure 6.5 An overview of nine FAO studies conducted in various regions and countries to identify and evaluate low-cost strategies to improve productivity while reducing livestock GHG emissions

Source: The World Bank (2025)

Note: Country experts and stakeholders were consulted to pre-select potential mitigation interventions. The table focuses on animal health (blue rows) and feed/nutrition (green rows) mitigation interventions and shows their effects on productivity gains ('prod.') and emission intensity reductions ('EI') in the context of the studies.



Part C

HORTICULTURE PRODUCTION IN SOUTH AFRICA

Chapter 7 An overview of horticulture production in South Africa

7.1 Overview

The horticulture sector consists of the production of fruit, wine, vegetables, tea, nuts and cut flowers. Over the past 15 years, it has contributed, on average, 28% to the total agriculture gross value in South Africa and employs over 220 000 people.

In 2023, the gross value of horticulture was R127 billion, a 16% increase from the previous year. South Africa's total agricultural gross value in 2023 was R435 billion, thus horticulture made a 29% contribution in that year (DALRRD 2024a).

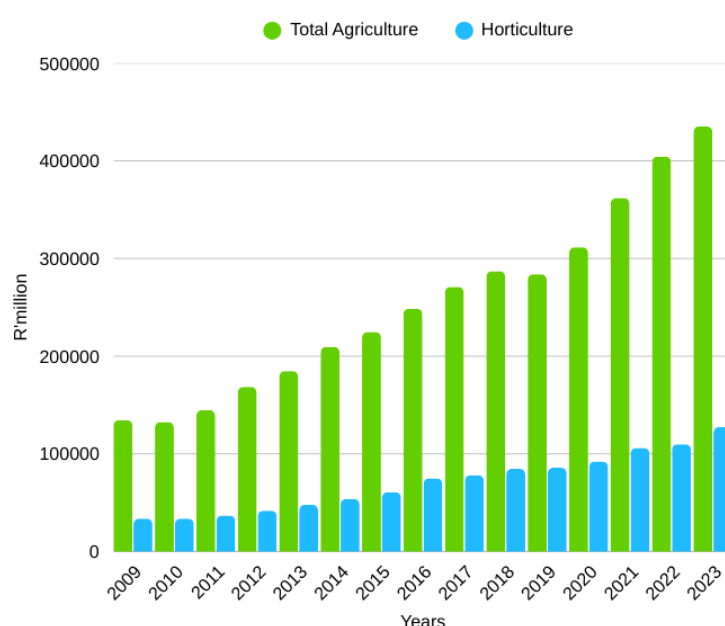


Figure 7.1 *Contribution of horticulture as a percentage of total agriculture gross value, 2009–2023*
Source: DALRRD (2024a)

According to the Agricultural Abstract (DALRRD 2024a), there is 3.89 million hectares of land¹² under horticulture in South Africa and 46% of this fall within the Western Cape. Given the dominance of the Western Cape, it is unsurprising that 43% of employment in the horticulture sector also stems from the Western Cape.

¹² Taken from Statistics South Africa Agricultural Census 2017. Land classified as horticulture is where the dominant branch of farming is horticulture (i.e. where more than half its total gross income comes from horticulture).

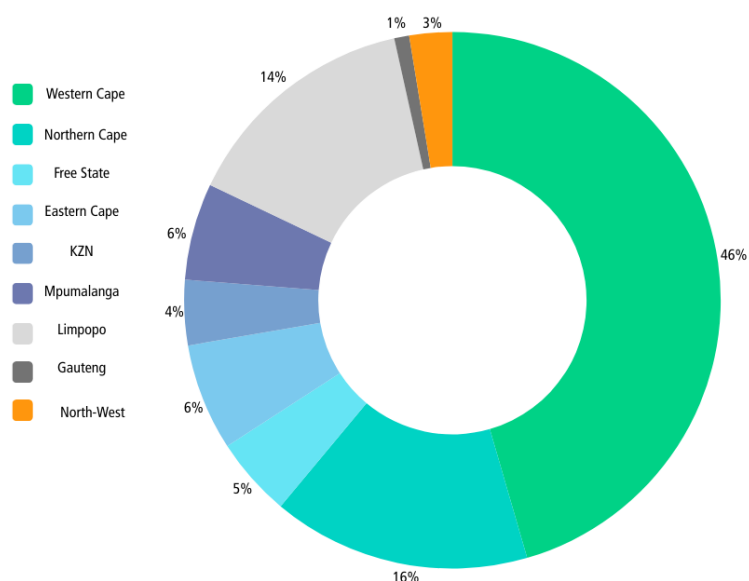


Figure 7.2 *Percentage breakdown of area under horticulture*
Source: DALRRD (2024a)

According to the TIPS report (Nyakabawo 2024), the total value of exports of fruit and vegetables amounted to R87 billion (4.3% of total exports). Of these exports, R76.3 billion is from fresh fruit and vegetables, while the remainder is from processed fruit and vegetables. There has been significant (88%) growth in fresh exports from 2013–2022, while processed fruit and vegetables has only grown by 22%.

The Netherlands and the UK are the main export markets for fresh fruit and vegetables and in 2022, the Netherlands had a 23% share of the market (Nyakabawo 2024). This has remained consistent over the past 10 years.

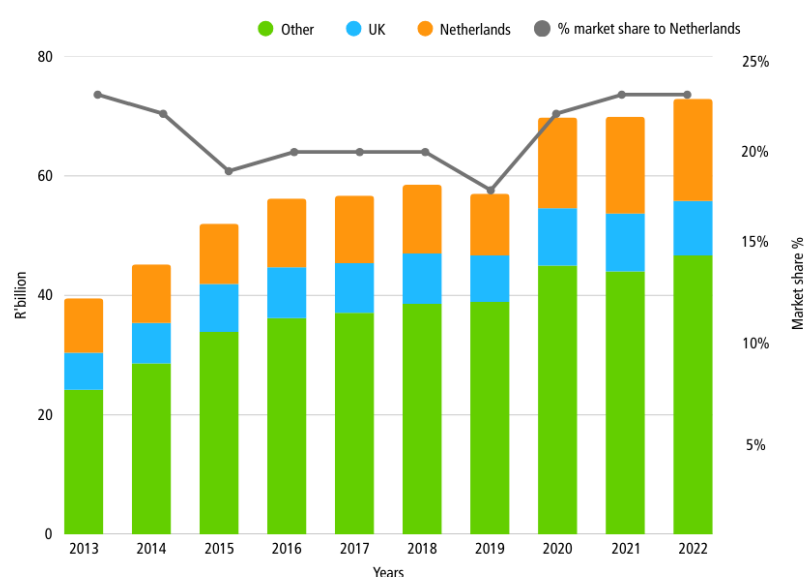
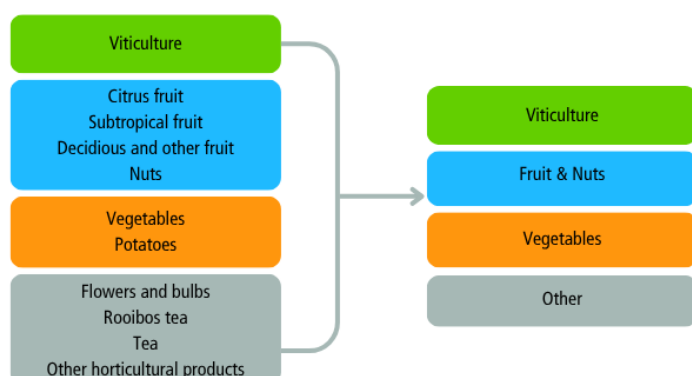


Figure 7.3 *Export value in R' billion of fresh fruit and vegetables to the Netherlands, UK and other countries, 2013–2022*
Source: Nyakabawo (2024)

For the purposes herein, horticulture has been divided into the following four categories: viticulture and table grapes, fruits and nuts, vegetables and other (tea and flowers).



Fruit and nuts are an important category, contributing an estimated R70 billion in gross value in 2023. Within this category, deciduous and citrus fruit production dominate the landscape, with deciduous fruit and citrus fruit both yielding an estimated R27 billion.¹³ Vegetables contributed R34 billion, with potatoes being the most valuable vegetable produced. Viticulture and table grapes contributed R19 billion, while other horticultural produce, such as tea and cut flowers, generated R3 billion in 2023 (DALRRD 2024a).

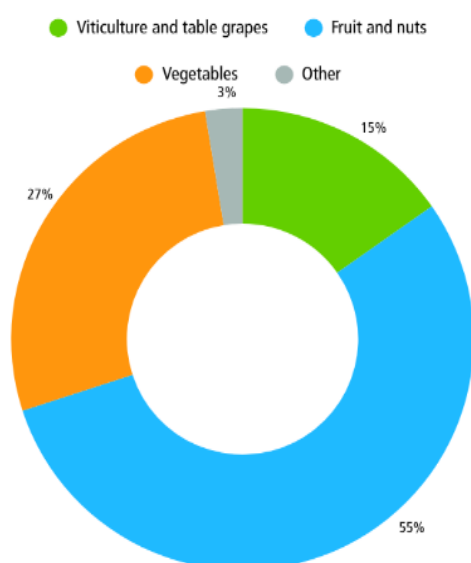


Figure 7.4 Breakdown of horticulture gross value per category according to DALRRD
Source: DALRRD (2024a)

Grapes, oranges and apples represent a significant share of the horticultural sector, constituting about 56% of the total value and production volume. These products have considerable trading value with the Netherlands, which is recognised as the primary market for South African oranges and the largest single export market for South Africa's table grapes, accounting for more than 40% of the total

¹³ Dried fruit is not included in this study, as that deals with the processing rather than production of fruit.

exports. The list below shows the top 10 horticulture products that account for 92% of the total value of horticulture output (DALRRD 2024a). In Figure 7.5, grapes incorporate both table and wine grapes.

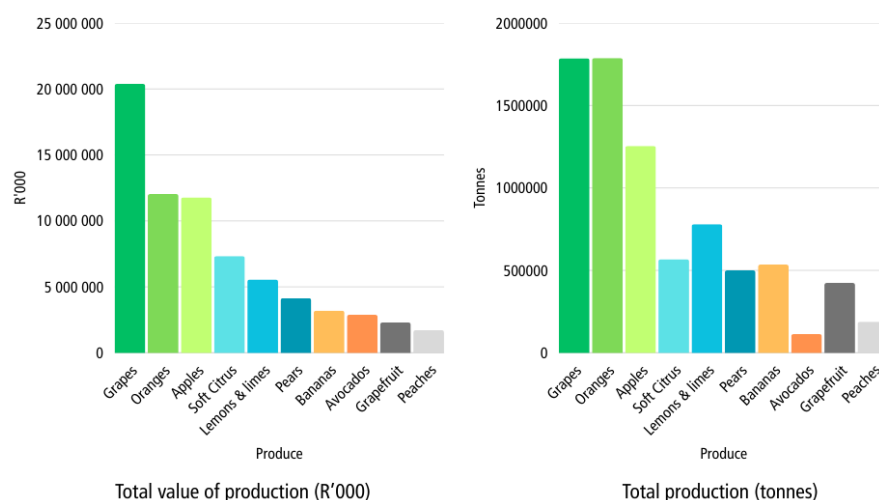


Figure 7.5 The ‘top 10’ horticultural produce based on value of production and total tonnage produced, 2023

Source: DALRRD (2024a)

7.2 Viticulture and table grapes

Viticulture is the cultivation and harvesting of grapes and this section looks at grapes that are used in viniculture (wine making) and table grapes for consumption. The gross value of table grapes in 2023 was R11.8 billion with a total production of 293 482 tonnes for the corresponding year. The area under table grape cultivation is 19 488 hectares and is predominantly located (61%) in the Western Cape. The sector employs 14 511 permanent workers and 84 000 seasonal workers.

For wine grapes, production in 2023 was 1.18 million tonnes from which 775.5 million litres of wine was produced. The area under wine grape vineyards is 87 848 hectares and is primarily located in the Western Cape. The sector employs 86 000 workers for both on the farms and in cellars.

The market for table grapes is mostly export-driven, with 70% of table grapes destined for the EU and UK. South Africa is the fourth largest exporter of table grapes in the world and therefore significant in the global market. The market for wine is mostly driven by domestic demand, with only 40% of wine being exported. The UK, Germany and the Netherlands are South Africa’s top consumers.

7.3 Fruit and nuts

Given the magnitude and significance of the fruit sector within horticulture, this section is further broken down into “deciduous”, “sub-tropical”, “citrus” and “nuts” sub-branches and further detail is explored further in Annexure 6. As Figure 7.6 shows, citrus fruit produces 45% of all fruit tonnage produced, followed by deciduous fruit (25%) and grapes (18%) (DALRRD 2024a). In terms of value of

production, deciduous fruit and citrus fruit each contribute 31% of overall gross value followed by grapes¹⁴ at 22% (DALRRD 2024a).

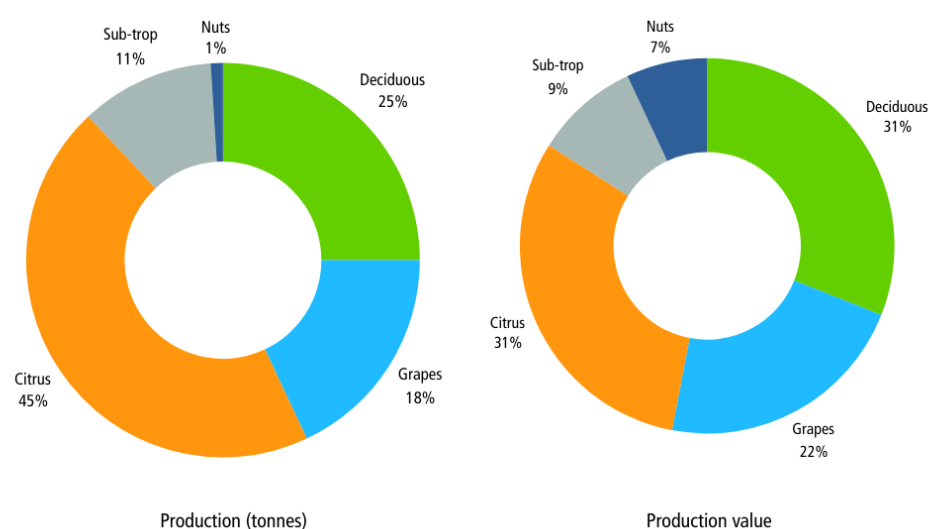


Figure 7.6 Break-down of fruit sector by production volume and value

Source: DALRRD (2024a)

In 2023, citrus contributed R27.5 billion in gross value and produced 3.6 million tonnes of fruit. There is currently just shy of 100 000 hectares under citrus with 46% of this grown in the Eastern and Western Cape. It employs 120 000 workers. Citrus exports are South Africa's single biggest agricultural export by value, with the EU being the main export market.

Deciduous fruit also had a gross value of R27 billion in 2023, with apples contributing R11 billion of this. There is 54 349 hectares under orchards and 2 929 hectares planted to berries, all of which primarily falls in the Western Cape. While only 40% of deciduous fruit is exported, 72% of berries is produced for the export market, destined mainly for the United Kingdom and Netherlands.

Subtropical fruit contributed R7.5 billion in gross value and produced 910 000 tonnes of fruit in 2023. Located in the provinces of Limpopo, Mpumalanga and KwaZulu-Natal, sub-tropical fruit is produced mainly for the domestic market.

Macadamia and pecan nuts are the most prominent tree nuts produced in South Africa, and both are significant global players. There is currently 68 556 hectares planted to macadamias and 37 035 hectares under pecan nuts.

7.4 Vegetables

Vegetable production contributed R34 billion in gross value in 2023, with potatoes being the most significant vegetable. In 2023, there was 2.41 million tonnes of potatoes produced, and 49 841

¹⁴ For the purposes of this study, viticulture and table grapes are grouped together and therefore deciduous fruit does not include grapes.

hectares planted to potatoes. It is estimated that the potato sector employs 50 000 permanent and 60 000 seasonal workers.

Tomatoes rank among the most widely consumed fruits and in 2023, half a million tonnes of tomatoes was produced. As with most vegetables, potatoes and tomatoes are produced for the domestic market and primarily sold on major fresh produce markets around the country.

7.5 Other horticultural produce

This section discusses the rooibos tea and fynbos cut flower industries. In 2023, there was 22 600 tonnes of rooibos tea produced contributing R362 million in gross value. The sector employs an estimated 8 000 workers and is situated mainly in the Western Cape. The fynbos flower cut industry is also located in the Western Cape and spans approximately 1 271 hectares. It generated R2.5 billion in 2023 and employs around 2 500 workers.

Chapter 8 Climate smart regenerative horticulture production: Evidence from the field

8.1 Environmental certifications

8.1.1 SIZA Environmental

The main sustainable certification standard within the horticulture sector is the Sustainability Initiative of South Africa (SIZA) and more specifically, the SIZA Environmental Pillar of Sustainability. It was established in partnership with the WWF-SA (the World Wide Fund for Nature, South Africa) and Blue North Sustainability for technical expertise.



It is based on leading international and local standards, national legislation and sound ecological principles and is designed to assist producers to evaluate their compliance and environmental risks at both a farm level and regional/catchment level (SIZA).

SIZA has been a GLOBALG.A.P. Community Member since 2017, sharing the brand mission of developing responsible production standards and capacity building activities that encourage the large-scale adoption of safer and more sustainable farming practices. The SIZA Environmental add-on is designed to minimise audit duplication. This add-on allows producers to demonstrate compliance with the GLOBALG.A.P. Integrated Farm Assurance (IFA) standard through a combined audit process (Global GAP website).

There are eight principles of the standard which are highlighted Figure 8.1.

SIZA	
Eight principles	
Commitment to implement management systems	1
Responsible management of waste	2
Make use of healthy soil practices	3
Control invasive alien plants	4
Improve water use efficiency	5
Reduce greenhouse gas emissions	6
Prevent contamination to soil and water bodies	7
Restore natural ecosystems	8

Figure 8.1 Key principles of SIZA environmental certification

Source: SIZA website (<https://siza.co.za/environmental-standard/>)

Focusing only on SIZA Environmental certification, according to the 2023/24 report, there are 1 202 member sites from the citrus commodities and 1 070 member sites from deciduous fruit commodities. Table grapes have 226 member sites while wine grapes have 175 members. In total, the horticulture fresh produce sector has 3 270 members registered and certified by SIZA.

What is key to note is that 94.82% of all pome fruit producers are registered with SIZA Environmental in addition to 68.4% of all stone fruit producers and 71.5% of all table grape producers.

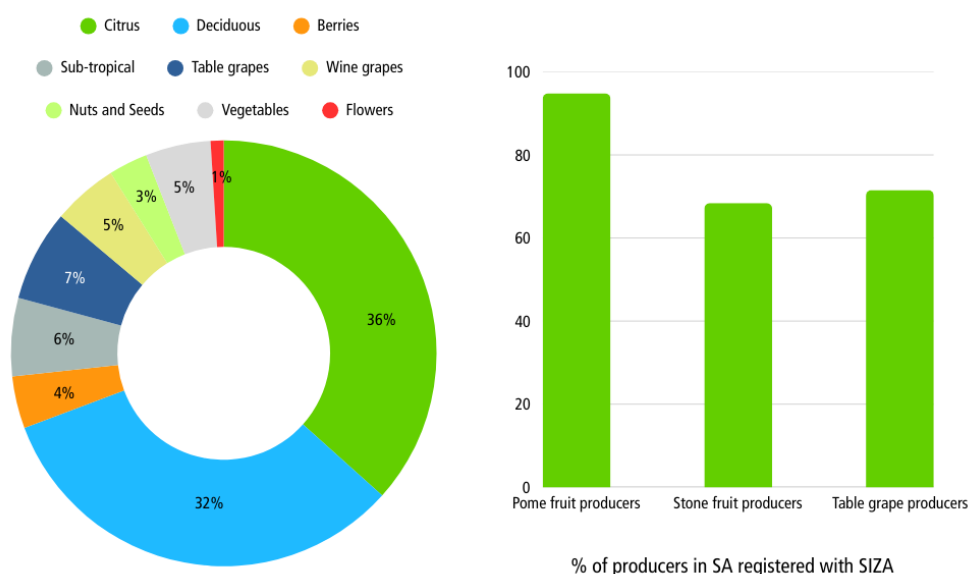


Figure 8.2 Breakdown of SIZA environmental certification records by commodities
Source: SIZA Environmental Monitoring and Evaluation Report (2023/2024)

8.1.2 Integrated Production of Wine (IPW)

For wine producers, there are a handful of different certifications available including their own Integrity and Sustainability Seal which meets the internationally recognised Integrated Production of Wine (IPW) criteria for sustainable standards. In 2022, more than 95% of wine farms were certified to use this seal.

The IPW scheme complies with international wine industry environmental sustainability criteria, including the 'Global Wine Sector Environmental Sustainability Principles' as published by the International Federation of Wine and Spirits (FIVS) and the 'OIV Guidelines for sustainable Viti-viniculture: Production, processing and packaging of products' as published by the International Organisation of Vine and Wine (OIV) (IPW Website). A unique aspect of the IPW is that it has been incorporated into the Wine of Origin seal that allows for a visual guarantee on the wine bottle for the integrity of origin and/or vintage year and/or cultivar, but also for sustainable production and traceability up to product level.

8.2 Industry platforms

8.2.1 Confronting Climate Change Initiative

Confronting Climate Change (CCC) is carbon footprint initiative that aims to support fruit and wine farms to identify and respond to the risks and opportunities associated with carbon emissions. The Confronting Climate Change (CCC) database demonstrates substantial engagement from various agricultural sectors in South Africa based on the number of hectares for which a carbon footprint calculation exists. Wine, citrus, table grapes, pome fruit and stone fruit industries all demonstrate significant involvement in carbon footprint calculations within the Confronting Climate Change database and this carbon footprint calculation tool is widely used in South Africa. The international user base is also growing and has a strong focus on supporting growers to calculate a high quality carbon footprint and to understand their own emissions with the view of setting emission reduction targets.

The CCC initiative works closely with the IPW and SIZA standards to ensure that the industry is well equipped to measure and understand their carbon emissions and to enable them to make informed decisions in the journey to reduce emissions. Annual industry benchmark reports are compiled based on the data captured in CCC and shared via the Fruit and Wine Industry bodies in South Africa.



8.2.2 Carbon Heroes

Carbon Heroes offers a digital self-disclosure platform, recognising agri-businesses that take action beyond compliance and understands the vital link between a healthy planet, thriving societies and robust economies. Carbon Heroes was developed by Blue North Sustainability, a South African consultancy with over a decade of experience in the food and agriculture sector. Since 2011, they have worked closely with businesses across supply chains – witnessing exceptional leadership, innovation and integrity that often go unrecognised. In response, Carbon Heroes launched in 2021 to highlight efforts in carbon reduction and has since evolved into a broader platform celebrating progress across all key areas of sustainability.

8.2.3 WWF Conservation Champions

The WWF Conservation Champions are landowners who commit to biodiversity-friendly and regenerative farming practices, conserve their natural areas and continually improve their water and energy efficiencies. WWF currently works with 60 Conservation Champions (WWF).

WWF Conservation Champions are environmental leaders in South Africa's wine industry, committed to biodiversity-friendly and regenerative farming. These landowners conserve natural areas and continually improve their water and energy efficiencies. In exchange for their commitment to nature and adhering to WWF's high standards, Conservation Champions proudly use the striking sugarbird and protea logo on their wine bottles to demonstrate their dedication to the conservation of the Cape Floral Kingdom's unique biodiversity.

8.2.4 Terraclim

For the agriculture industry, TerraClim stands out as a comprehensive online platform, providing granular climate and terrain data down to the farm and field level. This robust tool is designed to support informed decision-making for growers.

TerraClim delivers precise climate and environmental insights, enabling users to optimise critical agricultural practices such as planting, harvesting and resource management. The result is enhanced productivity and the adoption of more sustainable farming methods (TerraClim 2023).



8.2.5 Hortgro Climate Change App

A web application has been developed for Hortgro to serve as a science-based practical guide to pome and stone fruit producers in South Africa. The web application provides access to climate change risks, impacts and adaptation responses (Hortgro 2025).

8.3 Case Studies of climate smart regenerative agriculture practices within horticulture

The following section uses case studies to show examples of where and how these practices are being implemented across the horticulture sector.

8.3.1 Plant diversity and keeping soil covered

South African wine farmers are well advanced when it comes to the practice of cover cropping, and according to Diedericks, a soil scientist at Resalt, South African wine farmers are considered the world

leaders in this regard (Reyneke 2024). The reason for the uptake of planting diverse cover crops between the vineyards is the multitude of benefits it brings, such as moderating the temperature of the soils, improving water retention, reducing evaporation, the control of competitive weeds, improved soil structure for improved root development and the protection of microsoil organisms for improved soil health.

At Bosman Wine Farm, experimentation with cover crops found the red clover to work best in the battle against weeds given it is a hardy winter perennial. For the first three years it needs to be topped up, but afterwards it forms a thick layer which assists in outcompeting most weeds and has the ability to fix nitrogen (Kriel 2022a). For best results, the cover crops are supplied with water.

In spring, the cover crops need to stop growing to allow vines to flourish and to eliminate snail-friendly habitats, and so the cover crops at Bosman Family farms are rolled flat, instead of using pesticides. This allows them to decompose naturally, feeding the soil with essential nutrients and nitrogen. The mulch also improves the structure of the soil (Bosman Wines).



Figure 8.3 Left: Indigenous grass species planted between vineyards at Saltare's MCC vineyards; Right: Nativo's "weeds in bloom" cover crops

Sources: Saltare (2023); Nativo (nd)

Goedemoed is another example of a wine farms using an array of plants in their cover crops: in order to boost diversity, they collected leftover and damaged grain seed from Swartland and Overberg and sowed this into every fifth or sixth orchard row – clover, serradella, vetch, black oats, lupines and fava beans – this diversity of crops has helped to solve red spider mite problem.⁴

Nativo have moved away from common cover crops like rye, to "weeds*" for a number of reasons: 1) flowering plants increase insects and other life that are natural competitors to vineyard pests; 2) roots bind soil and help aerate it, and water reaches deeper (softens clay soil); 3) in winter they cover the ground and prevent excess evaporation of water enabling winter rainfall to infiltrate the soil better – roots do not go as deep as the old vines and therefore there is no competition for water; and 4) they die on their own and deposit an abundance of organic matter (compost) (Nativo nd).

*Weeds consist of Cape Marigold (*Arctotheca calendula*), Purple Echium (*Echium plantagineum*), Wild radish (*Raphanus raphanistrum*), Wild mustard (*Rapistrum rugosum*), Cape Wild Mustard (*Sisymbrium capense*), Common wild mustard (*Sisymbrium thellungii*), Yellow sorrel (*Oxalis pes-caprae*).

8.3.2 Reduction of pesticides and herbicides

In 2003, ZZ2 implemented *natuurboedery* philosophy to their apple and pear orchards. They decided that to control pests such as red spider mite, they needed to encourage a population of predators and, therefore, diverse cover cropping in the work rows was planted (Mouton 2024b).



Orchard insect diversity creates a favourable environment for biological control agents. For the past 20 years ZZ2 has not applied nematode or wooly aphid treatments to newly-established or older orchards. Further investigations to reduce or eliminate synthetic pesticides and herbicides (Mouton 2024b).



Tam Johnson from Du Roi Laboratory (Farmers Inside Track) explained that IPM solutions are a new sector, and uptake is slow due to insufficient data and expertise. Some farmers are using *Metarrhizium anispliae* which is a fungus that is used as biological pesticide to control pests. Practices of leaving the plantation fallow for a year before planting also reduces the population of unwanted pests (Van Rooyen 2013). Planting a variety of cover crops after the plantation is removed every 10 years assists in reducing the nematodes.

AgriStar, producer of Macadamia nuts, and Carbon Hero for three years, is actively reducing the use of harmful products (Carbon Heroes AgriStar). The current IPM programme includes the use of pheromones and naturally occurring insect-killing fungus (AgriStar 2021). These broad-spectrum biological products naturally control thrips, stinkbugs and mealybugs. In addition, the scouting team monitors the orchards daily, looking for pest presence and damage. This allows them to act as and when there is a problem and reduces the use of chemicals. They will introduce more biological products into their programmes to slow chemical resistance, grow the good predator population and spray less.



Source: Carbon Heroes AgriStar

Instead of using herbicides at Reyneke Farms, which is South Africa's only Biodynamic Certified wine farm, they outgrow them with beneficial plants or grasses. This is a way to build soil structure, fix nitrogen or use plants to bring up nutrients from deep down in addition to using plants that harbour natural predators (Vineyard Brands LLC 2020, 2021). Through applying a range of biodynamic practises, they saved R100 000 from spending on fertiliser, and R130 000 on organic compost, to zero spending. Furthermore, they diversified their income through introducing cattle into the vineyard. And productivity increased too – from yields of 8 tonnes per hectare when farming conventionally, to a record of between 10 and 11 tonnes per hectare in 2024 (Reyneke 2024).

However, regarding pests, they had a problem with snails. Initially they harvested the snails for escargot to France. But after the market only wanted the largest snails, they brought in 200 ducks and that sorted the snails out within a year.

Langplaas plants 400 hectares to vegetables, including sweet potato, carrots, beetroot and butternut. They produce 50–55 000 tons of vegetables with high nutrient value and this is because of their switch to regenerative farming in 2006. They have planted diverse species as cover crops, reduced their tillage and cut back on chemicals. They strive to increase the soil carbon and currently have 3–4%, which is above South Africa's average (Dempsey 2022).

8.3.3 Minimal tillage

Middelplaas: Mr Fritz Breytenbach, from Middelplaas in Robertson reaped the benefits of minimum tillage after two years of introducing the practice. He noticed that the microbial life was being damaged each time the soil was turned, or a ripper was used, resulting in poor soil structure and poor production. Since 2012, the average production of wine grapes has been 30 t/ha, almost double the region's average. Mr Breytenbach explained that "it is tilling that injures the roots that feed the plants and provides access to nematodes (Botha 2016)". Combining other biological farming practises, such as oxygenated water (Puricare's Soilcare unit in his micro-sprinkler system) and the Albrecht system to analyse and monitor soil nutrient levels, his production volumes began to increase in conjunction with decreasing input costs (Kriel 2017).



Figure 8.4 Mr Breytenbach among the vineyards

Source: <https://realipm.co.za/the-best-peaches-come-from-robertson/>

ZZ2: A report in 2011 investigating ZZ2's *natuurboerdery* explained that ZZ2 believes that minimum tillage to be the most sustainable method for soil preparation as it enhances soil health (Taurayi 2011).

All the land prepared for avocado production utilises no-tillage, with only the planting stations tilled. The inter-row spaces maintain a grass cover which is maintained by slashing. In 2011, only 5% of the cropped area for tomato production was under minimum tillage with 18% incremental annual targets. A challenge has been finding the right equipment for minimum tillage so that it is compatible with other operations. Moving towards 100% minimum tillage will result in 75% cost savings on soil preparation through less use of tractors.

ZZ2 philosophy for minimal soil disturbance

- Improving soil structure and texture
- Increasing water penetration and soil water holding capacity
- Increasing organic matter content
- Improving soil microbial life
- Protection of the soil from erosion



Figure 8.5 *Tomatoes and avocados under minimum tillage at ZZ2*

Source: Photos in Taurayi (2011)

Klipopmekaar: In the Cedarberg at Klipopmekaar Organic Rooibos Farm (Klipopmekaar website), a no-till approach is used to prepare the fields. Planting takes place in autumn and ahead of cultivation, they are ripped with advance custom-made tine implements which do not overturn the soil but rather create deep non-invasive furrows in which the rooibos seedlings can take root. Apart from the benefits of improving soil quality and reducing compaction, it also provides cost savings as it requires less labour, fuel, irrigation (due to higher water content in the soil) and less machinery (Klipopmekaar 2009).



Figure 8.6 *Field preparation at Klipopmekaar Rooibos Farm*

Source: <https://www.klipopmekaar.co.za/rooibos-farming-production-process/>

8.3.4 Animal integration

Bosman Wine Farms use dormer sheep to control weeds, fertilise the soil and introduce beneficial organisms (Kriel 2022a). On their farm Lelienfontein near Wellington, sheep are brought in annually from May for the winter months once the vines have built up a reserve and gone into dormancy. They have found this far more efficient than managing the weeds by hand and environmentally beneficial ensuring that the top layer of soil is not disturbed when taking out the weeds. Once the buds break, the sheep are taken away from the vineyards. According to PD Bosman, viticulturist at Bosman Adama: “We don’t want the sheep to graze the vineyards during the active growing phase, as they’ll strip the vines of leaves that are important for photosynthesis and protect the berries against sunburn”.



Adjustments had to be made to accommodate the sheep on Lelienfontein. Where the old vines were planted on a vertical shoot trellis system, the organic vines are planted on a high wire system to prevent the sheep from damaging the vines.

Figure 8.7 Integrated grazing at Wellington Farm

Source: Bosman Wines website

Hartenburg Wine Farm, South Africa's first wine farm to achieve regenerative verification under the Ecological Outcome Verification (EOV) framework, introduced cattle to the farm in 2017 (Hartenburg Estate website). Soil analyses prove the benefits of adding nutrients to the soil, stimulating plant growth and aerating the soil



Source:
<https://www.capetownexperiences.co.za/tour-hws/hartenberg-wine-farm>

At Goedemoed, they moved away from mechanical methods of dealing with weeds – not due to the expense, but because of the threat of compaction (Kriel 2022b). They have experimented with sheep, pigs and chickens. The Dorper sheep were too destructive, even after hooking nets on supporting wires of the trellis systems for protection. Initially there was concern that the animal impact might increase compaction and affect plant growth, but later it became evident that the grazed areas contained up to 30% more plant material compared to areas where no grazing took place. They've settled on 290 lambs and added pigs and chickens to tackle bindweed (pigs) and pests (chickens).



Source: Kriel (2022b)

8.3.5 Alternatives to fertiliser: relying more on biological nutrient cycles

For the past 20 years, Umvangazi Farms, a macadamia producer, has been embracing their philosophy of farming the soil back to health (Carbon Heroes nd). They incorporate large volumes of organic material back into the orchards. The organic material is derived from pruning on the farms and the husks that are removed after harvesting are then composted and used on the orchards.

ZZ2 produces 2.5 million litres of compost tea and 50 000 cubic metres per year.

ZZ2 believes in a closed cycle by feeding the nutrients to the plants, which in turn are harvested back into compost to be made available for planting again.

ZZ2¹⁵ produces and utilise compost and compost tea (FreshFruitPortal 2017). For the apple and pear orchards they use the ratio of one cubic metre of compost per 100 metres as this provides the biological boost to the soil. After applying the compost, they cover with wood chips or straw to shelter and feed the soil microbial community. To avoid excessive potassium and inefficient nitrogen, leaf and soil analyses together with thorough crop load and visual tree assessments are performed (Mouton 2024b).



Source: FreshFruitPortal (2017); <https://www.zz2.co.za/archives/zz2-nature-farming-takes-compost-to-new-level>

The application differs according to produce and so for tomatoes, they need a plant-feeding compost with nutrients in the compost. But for avocados, compost which focuses on the soil's physical characteristics, "soil conditioning compost", is used. Compost also has a disease suppressive effect in the soil, especially against soil-borne diseases (FreshFruitPortal 2017).

Bosman Wines use aerated compost teas are used to feed the soil and micro-organisms, which in turn supply the vines with nutrients (Kriel 2022a). The tea also helps to accelerate the breakdown of cover crop plant material. The tea is formulated by Ecosoil based on soil and leaf analysis results. According to the technical manager Dan Swart, "The recipe is specifically formulated according to the needs of our vineyards and adapted over time to accommodate different stages of growth. Ecosoil also supplies the farm with a starter and the raw material used in the compost tea (Bosman Wines 2024)."



Source: Bosman Wines (2024)

The tea is brewed on the farm and supplied to the vines via fertigation within four hours of brewing to retain its efficacy. It is considered better than organic fertiliser which requires rain to wash it into the soil. They have also started using it in their conventional vineyards which has reduced amount of fertiliser needed there. Incorporating organic inputs has also helped to buffer the farm against the huge spike in fertiliser and pesticide costs. "While the price of many conventional inputs has almost doubled over the past couple of years, the price of organic inputs has seen an inflation-related rise. The diversity of good organic products on the market, especially liquid organic fertilisers, has also

¹⁵ Nature farming principle of re-establishing balance, encouraging biological diversity in the orchard.

increased greatly, making it easier for farmers to use these options,” says Jannie, the chairperson of Bosman Adama wines (Kriel 2022a).

8.3.6 Water management

There are many fruit farms who are implementing water management techniques with the outcome of water conservation. This section aims at detailing some of the practises and systems.

The apple farm in Elgin called Dennegeur is fine tuning their water management system by implementing the following:

1. Installing two weather stations recording maximum temperature and humidity which influences time and duration of watering schedule.
2. Making changes to irrigation schedules based on state of the trees (bearing, 1/2 bearing and non-bearing).
3. Designing the layout and orientation for optimal water retention and controlled runoff.
4. Planting wind rows planted in prominent areas to slow down surface windspeed (which affects surface soil drying out).

Dennegeur farm has also made use of the Sherpa tool for developing their Environmental Management Plan (Blue North Sustainability, Case Study 2 Dennegeur).



Dreem Fruit, a stone fruit farm in the Breede Valley is improving their water efficiencies via the following practises (Blue North Sustainability, Case Study 4 Dreem Fruit).

1. Ensuring high value crops are planted when using the scarce water resources as this is the most economical and environmentally sustainable choice and why they moved away from wine grapes.
2. Utilising old vineyards as chips for mulching.
3. Integrating technology in the form of soil moisture probes when irrigating has improved their approach to water management.
4. Fruitlook assists in seeing how crops respond as part of the bigger water cycle of their region.
5. Undergo tests to compare drip to micro irrigation and no evidence yet. Currently 90% of new planting have been to drip, but this is easily interchangeable.



Figure 8.8 Mulching
Source: Wessels in Blue North Sustainability Case Study 4

They also experimented with “weed mats” from Turkey, but they saw no change in weeds or soil moisture.

Morgenzon, a plum and mixed farm in the Cape Winelands have replaced the non-indigenous planted wind breaks with indigenous trees which has resulted in big water saving. This has also improved their biodiversity by creating ecological corridors. Other water saving techniques have included mulching



Figure 8.9 Drip irrigation on new orchards
Source: Wessels in Blue North Sustainability Report Case Study 4



Figure 8.10 Netting
Source: Wessels in Blue North Sustainability Report Case Study 6

(by utilising the cut trees and using the chippings as organic mulch) and developing netting which has resulted in 15–20% water savings (Blue North Sustainability, Case Study 6 Morgenzon).

During the drought they had to change their irrigation schedules and they realised that they had in fact been over-irrigating and since adjusted the depth of their irrigation.

Boomerang apple farm in Elgin also employs water monitoring devices every 10 cm (0–80 cm deep) to measure moisture content, soil temperature and root activity. The probes indicate when cycles need to be adjusted. In the future, they hope to install an automated water programme (Blue North Sustainability, Case Study 1 Boomerang Fruits).

After the 2015–2018 drought, de Keur Estates (fruit farms in the Koue Bokkeveld region), developed methods to use water more sustainably which included taking out older orchards earlier and planting more waterwise new ones, improving soil preparation using narrower rows to limit evaporation. They use wheat straw on the beds to reduce evaporation, drip irrigation and a smaller radius on their micro spitters; regenerative practises and nets to cover orchards which has saved 15–18% of water with the additional benefits of protection against sunburn and hail damage (Blue North Sustainability, Case Study 3 de Keur). Anton de Jager, head of de Keur's Regenerative Agriculture, took courses from Dr Elaine's™ Soil Food Web School.



Figure 8.11 Wheat straw for mulch (left) and netting over fruit trees (right)

Source: Wessels in Blue North Sustainability Report Case Study 3

Karin Cluver, the production director at De Rust, a pome fruit farm in Elgin, has been using Fruitlook since 2012. It gives them an overview of the farm that isn't possible by walking through the orchards. By monitoring the Biomass Production and Evapotranspiration (ET) stress parameters, they are able to identify seasonal irrigation issues and accurately calculate relative water use for each block per season and improve efficiencies. It also assists in picking up variations. Karin also employs her own drones to capture infrared images to monitor water stress within the fields during the season. They also integrate data from soil probes to evaluate the effectiveness of their irrigation systems at various locations within our blocks

Fruitlook utilises remote sensing providing a spatial overview of the fields, giving overall performance of all orchards (and vineyards), allowing for easy monitoring of spatial variations within blocks.



8.3.7 Energy efficiency and carbon emission reduction

Boschendal farm, located in Franschhoek, is committed to practices which fall within the definition of climate smart regenerative agriculture. It has introduced innovative ways to reduce carbon emissions, which in turn reduce input costs. In addition to solar installation, which to date has contributed to a reduction of 6 217 tonnes of CO₂ (Boschendal website), they have developed a trellising system for plums that has made a significant impact.

According to the CCC benchmark, which explains where the emissions are generated from, electricity, nitrogen fertiliser and diesel are their greatest contributors to carbon emissions at a farm level (Blignaut nd).

The trellis system design means that there is a double row of trees on the ridge, with the trellis height only up to 2 m high (the shorter trees allow for enough sunlight to reach the orchard). The trees are 1.5 m apart with an additional 1 m between the rows. This design allows for a higher density of trees: 3 810 trees/hectare and an increased yield of 20–40% (Blignaut nd).

Given this design, the diesel for fuel is reduced when spraying and 120–150 litres/hectare is saved (at R15/litre is equal to R1 800–R2 250 per hectare). This translates to 337.2–421.5 kgCO₂e/ha. Furthermore, less protection plant products are needed as the spraying is more effective, thereby saving 500–700 litres of product/hectare. They also measure soil moisture every hour for every hectare planted and with this precision irrigation, they need to pump less, saving 30% electricity and water and further reducing their carbon emissions.

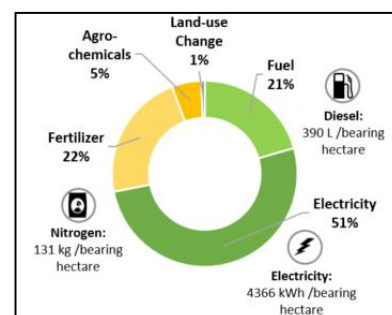


Figure 8.12 CCC Benchmark analysis showing where emissions are generated at farm level

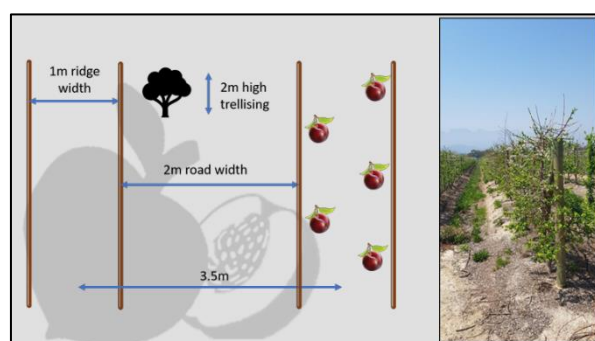


Figure 8.13 Trellis design at Boschendal farm that reaps carbon emission and cost savings

Chapter 9 The cost and benefits of CSRA within horticulture production

9.1 Introduction

Improving the performance and competitiveness of the agricultural sector is of strategic importance to the horticulture industry and these improvements need to be cognisant of the changing ecological context and therefore need be climate sensitive (Addison 2019). Within horticulture, much of the focus is aimed at enhancing the vineyard or orchard ecosystems and, therefore, the emphasis is placed on soil ecology. Chapter 0 Section 0.3.4 states how healthy soil is the core desired outcome of climate smart regenerative agriculture (CSRA) and the case studies above and discussion below highlight this.

Storey, who founded Nemlab in 1987 and co-founded Soil Health Support Centre in 2015 based in Stellenbosch, shares how soil is critically important for farmers within the horticulture sector, explaining that “a healthy soil is a stable soil, rich in biological diversity, with high levels of internal cycling of nutrients and with resilience to stress factors. The assumption is that increasing soil organic matter will enhance soil biodiversity, improve nutrient cycles and improve production overall” (Mouton 2025; Addison 2019).

9.2 Environmental benefits

Cover crops: plant diversity and keeping soil covered

There is much focus on cover crops, and this is because it is a key component of CSRA practises and a popular application for farmers in horticulture, especially since soil management is one of the key practices that influences the vegetative and reproductive activity of an orchard and vineyards (Giacalone et al. 2021).

It is estimated that 95% of life on land resides in the soil and most carbon comes from plant carbon. Living root exudates are rich in carbon. In return for this liquid carbon, microbes and beneficial fungi provide minerals and trace elements essential for plant health and vitality (Jones 2018).

Plants convert the carbohydrates to feed soil microbes and different plants, which means an range of carbohydrates result in a diversity of soil micro-organisms. Living roots are the easiest source of food for soil microbes and cover crops planted all-year feed the foundation species and root-soil interface of the soil food web. Living or dead plant roots, crop residues and organic matter feed members of the soil food web (Jones 2018).

Since permanent crops cannot be easily rotated, crop diversity is built into the orchard or vineyard systems using cover crops grown in association with trees or vines (Swanepoel 2021). As Chapter 0 explained, cover crops contribute to ecosystem processes, enhancing nutrient cycling and fostering diversity.

Cover crops improve soil health, soil moisture and temperature regulation, weed and pest control, forage production and other biodiversity benefits. Literature reveals that cover crops can also increase soil organic stocks, with sequestration rates highest during the first few years (Giacalone et al. 2021). For deciduous crops, cultivation of annual cover crops in the winter rainfall areas is important as these

cover crops can utilise winter rainfall and naturally die-off in the summer prior to fruit production season. The method and timing of crop termination has a strong role in determining the extent of weed suppression and impact on soil health (O'Brien et al. 2025).

Protecting the soil with mulch or crop residues, when cover crops are not used, is also an important practice in orchards and vineyards (Swanepoel 2021). Mulches improve water infiltration, reduce soil erosion, and suppress weeds by blocking sunlight (Kornecki & Kichler 2023 in O'Brien et al. 2025). Given the benefits of water retention, cover-cropping and mulches can compensate for more erratic rainfall or droughts often experienced in South Africa (Swanepoel 2021).

According to Ramos et al. (2010 in De Leijster et al. 2020) cover crops used across almond orchards in Spain showed improved pollination activity and soil organic carbon by 56–67% and other studies showed it reduced soil erosion by 51–95% (De Leijster et al. 2020).

An agricultural survey, undertaken in the United States by the Sustainable Agriculture Research and Education (SARE) programme and Conservation Technical Information Center (CTIC) over 2019–2020, surveyed 235 farmers within horticulture, and enquired into farmers' motivations for adopting cover crops. Table 9.1 shows that the overriding reason was for improved soil health, followed by weed management and thirdly, a reduction in soil erosion (Myers and LaRose 2022).

Table 9.1 *Motivation for adopting cover crops within horticultural farms*

Soil Health	94%
Weed management	81%
Erosion reduction	71%
Water/Rainfall infiltration	63%
Pest control and harbouring beneficial insects	< 50%

Source: Myers and LaRose (2022)

Locally, there have been a few cover crop trials that have taken place to assess the environmental costs and benefits of cover crops. HortGro's Science Crop Protection Manager, Matthew Addison along with Hendrik Pohl initiated cover crop trials in deciduous fruit orchards in the Koue and Warm Bokkeveld back in 2017. The initial findings after four years included mitigation against heatwaves, with covered soil showing a 10–15-degree difference with barren soil. There was also an increase in nematode diversity which showed a stable system. There was increased bee/pollination activity. Other benefits included a stable orchard floor which meant the roots were anchored and could absorb water better. Since the cover crops draw up nutrients, when they are mown or rolled, the nutrients are released into the soil resulting in better availability of plant nutrients. The last initial finding consisted of improved carbon content (Steenkamp 2021a; Mouton 2022a).

Cover crop trials have also taken place to assess the impact within viticulture: the Gen Z Vineyard project establishing cover crops trials between April and May 2021. Gen Z together with Agricol and Barenbrug established 11 cover crop trials and together with Winetech and Barenbrug hosted grower days with grape producers, wine managers and viticulturalists to discuss the findings and share best practises (VinPro 2022).

Additionally, Dr Fourie published the book '*Cover Crops in South African Vineyards*' in April 2022, which describes the interaction between cover crops with vineyards, and which is based on a culmination of 50 years of research on cover crops at the Nietvoorbij research centre based in Stellenbosch. It assess all the benefits of cover crops across different regions and soil types in addition

to evaluating management strategies. (Link to online book: <https://user-hpa96tt.cld.bz/COVER-CROPS-in-South-African-Vineyards.>)

Chemical inputs

Modern agriculture routinely uses intensive techniques and various pesticides to manage pests, weeds and pathogens. Since 1990, pesticide use has surged by about 50%, with around 4 million tonnes applied annually (FAO 2022 in Jeyaseelan et al. 2024).

The reduction of chemical inputs is another main practise within CSRA in horticulture, and this is because research is showing that plant-dependent microbes are negatively impacted by the use of ‘-cides’: herbicides, pesticides, insecticides and fungicides. The use of these chemicals reduces nutrient uptake, compromising the plant’s immune response and often requiring even further use of chemicals (Jones 2018). Pesticides and insecticides are reported to degrade microbes’ structure, cellular process and distinct biochemical reactions at cellular and biochemical levels (Jeyaseelan et al. 2024). Storey explains how it all comes back to soil and how “healthy soils work every day to sustain life on earth, while sick soils must be chronically medicated with chemical inputs such as fertilisers and pesticides” (Mouton 2025). She also reminds producers that minimal disturbance isn’t only about tractors and tillage but explains that it is also chemical and biological and explains that products can also disturb the soil balance (Mouton 2025).

Other negative repercussions of using these inputs, includes the development of pest resistance, the potential harm of non-target organisms, environmental contamination and public health. It is therefore important that climate smart regenerative agriculture aims to minimise the use of synthetic and harmful chemical additives to the soil, while balancing the need to meet export standards.

As a result, many producers implement an Integrated Pest Management Strategy. Integrated Pest Management (IPM) is essentially a decision-making process that focuses on pest prevention and aims at using pesticides only when necessary (Green et al. 2020). IPM programmes typically follow a four-tiered approach that involves:

1. Pest identification and monitoring
2. Setting of action thresholds
3. Prevention
4. Control – this follows the most effective and lowest risk options and may be a combination of biological control, cultural control, physical and mechanical controls or chemical control (EPA website)

Matthew Addison, Crop Protection Manager at Hortgro Science, defines IPM as “the management of pest and disease populations using a variety of methods including physical, cultural and biological agents” (Steenkamp 2021b).

IPM environmental farm benefits include (Steenkamp 2021b):

- Reduction in the need to use pesticides
- Reduction in damage to crops and the environment
- Promotion of healthy crops and plants
- Reduction in potential water and air contaminants

Minimal soil disturbance

According to Strauss et al. (2021), macro-, meso- and microbiota¹⁶ are found in the top few centimetres of soil and this layer is the most vulnerable to degradation. Minimal soil disturbance improves the water cycle and mineral cycle ecosystem processes as outlined in Chapter 0. Conservation tillage practices help minimise both wind and water erosion by maintaining soil structure and cover, which reduces the loss of this fertile topsoil. It also promotes the accumulation of organic matter in the soil, which improves soil fertility and microbial activity.

Furthermore, research in cropping systems has shown that no-tillage enhances soil organic carbon sequestration with West and Post (2002) reporting that a change from conventional tillage to no-till could help sequester between 43 and 71 grams of carbon per year, 5–10 years following the conversion (Strauss et al. 2021).

Soil disturbance can reduce microbial activity, which is essential for aggregation. Soil aggregates are clusters of soil particles held together by organic matter and minerals. Aggregation improves soil stability, aeration, infiltration and water holding capacity. Consequently, tillage can destroy the habitat of beneficial species and the beneficial species themselves, disrupt soil structure, and accelerate organic matter loss, leaving bare soil that can increase erosion and the risk of compacted soil (Muhie 2022).

In a study De Leijster et al. (2019) showed that under agroecological management, Mediterranean almond plantations in comparison to conventional tillage, had the potential to improve provisioning services (nutrient cycling, carbon stock, habitat provisioning, pest control, pollination and food provisioning) by 17–24%.

Livestock integration and alternatives to fertiliser inputs

The integration of livestock into vineyards and orchards is being advocated for their management contributions such as weed control and the potential to improve aspects of soil health (including nutrient cycling, organic inputs and soil microbial biomass). There are many factors that determine the impact of livestock integration such as the timing and duration of grazing period, and their movement through the vineyard as well as the size, type and number of animals used (O'Brien et al. 2025). Integrating sheep in vineyards seems to be quite feasible in the period of vine dormancy/winter months, whereas more effort (such as vine training to ensure the height of the vine is raised) is needed to integrate sheep all year round. (Schoof et al. 2021).

In Brewer et al. (2023) they showed that *high-density, short-duration rotational grazing* management in perennial croplands holds significant potential to increase soil organic carbon (SOC) storage in the vineyard subsoil (30–40 cm deep). The study which examined eight commercial vineyards, found that grazing for over 10 years shows increased soil microbial biomass, higher microbial activity and carbon use efficiency in comparison to vineyards without grazing.

A reduction in synthetic fertilisers is promoted under CSRA practises because they can be detrimental to soil health and have associated high greenhouse gas emissions (GHG). Literature reveals that biochar, composts, farmyard manure, cuttings from vines and trees are often used in viticulture (O'Brien et al. 2025). Application of composts averaging 4 tons/ha/year over several years (5 years plus), can result in increased soil nutrients: nitrogen (N), phosphorous (P), potassium (K), Soil

¹⁶ Examples of macrobiota include earthworms and large organisms visible with naked eye, mesobiota include organisms sized 200 µm to 2 mm such as mites and microbiota include microscopic organisms which require magnification to see such as bacteria.

Organic Matter content and microbial biomass) (O'Brien et al. 2025). Additionally, aggregate stability and soil structure are improved, which leads to better water infiltration and retention in the soil (Laird et al. 2010 in O'Brien et al. 2025).

Water Management and Energy Efficiency

Water management applications such as improved monitoring via probes, irrigation efficiencies such as drop or micro-irrigation and other activities such as the removal of alien vegetation in catchment areas, all play a key role in water conservation. Furthermore, energy efficient investments such as solar power, reduce the reliance on electricity and in turn reduce greenhouse gas emissions.

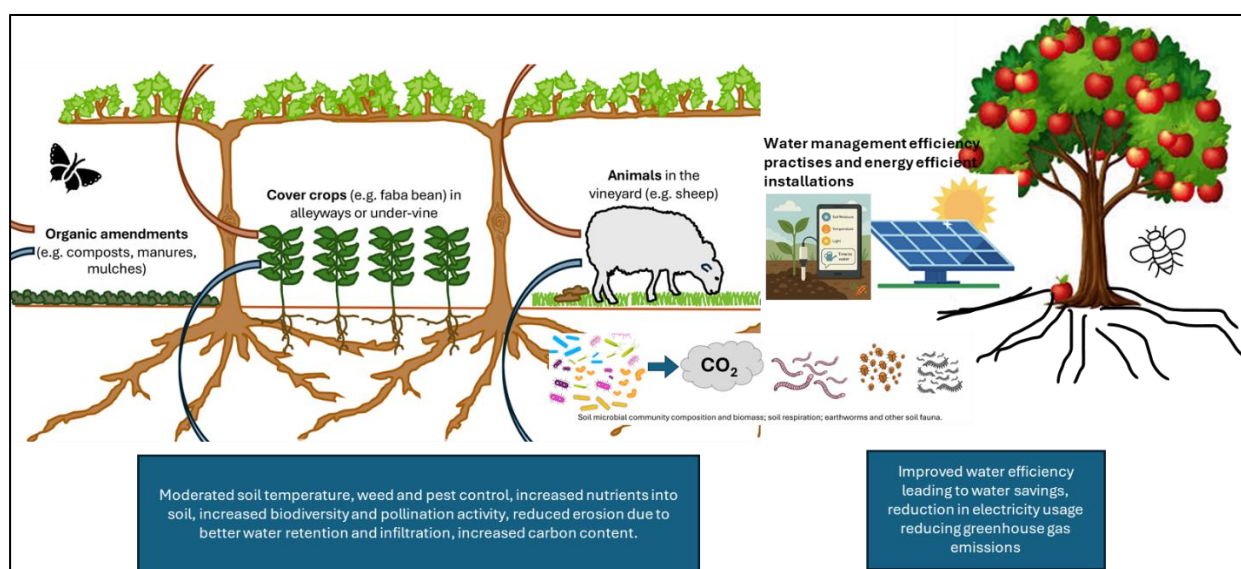


Figure 9.1 Illustration of the environmental benefits of CRSA practises within horticulture

Source: Adapted from O'Brian et al (2025)

9.3 Environmental costs

The activities discussed above such as cover crops (especially when legumes are used), application of organic amendments and the use of livestock within orchards and vineyards tend to result in short term spikes of nitrous acid (N_2O). The integration of livestock can also cause localised spikes in methane CH_4 and carbon dioxide CO_2 (O'Brian et al 2025).

However, these environmental costs need to be viewed in context, since these emissions are very low in comparison to other agricultural GHG sources such as synthetic N fertilisers (O'Brian et al. 2025). Furthermore, a study by Lazcano et al. (2022 in O'Brian et al. 2025) revealed that emissions from livestock had no significant effect on the cumulative emissions of any of these GHGs.

9.4 Financial benefits

Cover crops

The agricultural survey conducted by SARE programme and CTIC in the United States conducted a series of surveys to assess farmer's experiences with cover crops. In the 2019–2020 survey, 235 horticulture farmers were surveyed, the majority growing vegetables. The survey inquired about the respondents' perspectives on the impact of cover crops on overall profitability (Myers and LaRose 2022). While 38% replied that cover crops have no significant impact on profit, 23.4% responded that it had a minor impact and 34.8% a moderate impact on increasing net profit. This shows that almost 60% of the farmers had some positive impact on increasing net profits. A total of 3.8% of farmers responded that cover crops have a minor impact on decreasing profit and this is presumably due to the cost of seed.

Table 9.2 *Perceived impact of cover crops on farmers' net profit within horticulture*

Negative impact (profit decrease)	3.8%
No impact on profitability	38%
Minor impact on profitability	23.4%
Moderate impact on profitability	34.8%

Source: Myers and LaRose (2022)

The cover crop trials within fruit orchards that took place at the Warm and Koue Bokkeveld regions shared the following benefits which have direct financial implications. Cunningham noted that apple production costs per hectare sit between R200 000–R220 000 and therefore an additional R1 000/ha for cover crop seeds is not an expensive way to improve soil. However, further research is needed on quantifying these financial benefits.

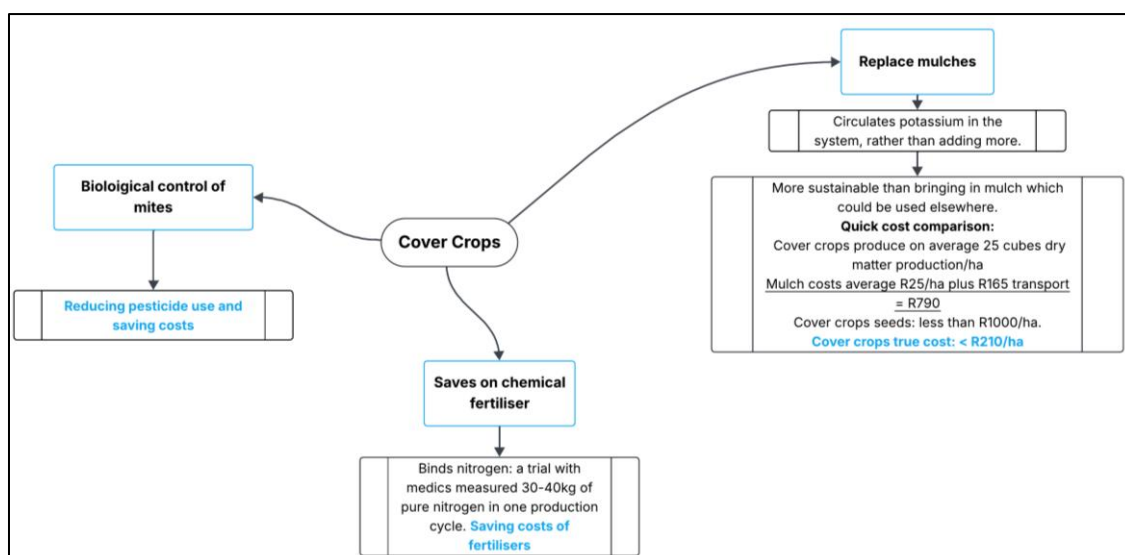


Figure 9.2 Mindmap showing initial findings of the benefits of cover crops within orchards taken from four year trial in the Warm and Koue Bokkeveld that can be translated into financial cost savings

Source: Steenkamp (2021a), Mouton (2022a)

Ivan Jansen van Rensburg (the Barenbrug agronomist) explained that cover crops within vineyards have important financial benefits given the rising input costs of fertilisers and chemical inputs and the stricter measures on chemical use in vineyards by export markets (VinPro 2022). At Reyneke they claimed a reduction in R100 000 in fertiliser and R130 000 in organic compounds.

However, it appears that while these trials assessed the environmental aspects, the impact they have on fruit quality, yields and other economic parameters has not been researched and therefore there is need for further research to quantify these outcomes.

Chemical Inputs

Adopting CRSA practises that limit or reduce chemical inputs, result in immediate cost savings.

The adoption of IPM solutions is also a cost-effective approach as it is underpinned by economic efficiency and a smart allocation of resources. The approach means that the costs of biocontrol are weighed against the economic damage of pests and disease and therefore eliminates unnecessary and costly treatments. It also emphasises preventative measures like crop rotation and cover crops, and aims to prevent pest infestations before they escalate (Koppert website 2024).

Financial benefits include a cost-effective solution to pest control. With the international markets constantly pushing for fewer chemicals, IPM can delay and or prevent pesticide resistance and enhance biological control.

Minimal soil disturbance

Moving away from conventional tillage towards conservation or no-till, results in cost savings of fuel and labour as less machinery is needed.

Livestock integration

Schoof et al. (2021)'s study reviewed livestock integration within vineyards in Central Europe and found that for winter grazing, vegetation control, followed by fertilisation effects were the top benefits. Within summer/all year grazing, vegetation control was the top benefit given that is being grazed during the growing season. Leaf pulling *within* the grape zone was also a top benefit while additional benefits included savings on machinery and herbicides, marketing benefits and the prevention of soil erosion.

Nitsch et al. (2017 in Schoof et al. 2021) investigated the integration of sheep grazing in New Zealand vineyards. Winegrowers saved costs by using less herbicides and a reduced mechanical weed controls due to the impact from sheep grazing. Additionally, they examined that they could potentially save costs by allowing the sheep to pluck the leaves in the grape zone, which again would usually be performed manually or mechanically thereby saving fuel or labour costs.

The integration of livestock also enables financial diversification and enabling another income stream (Ochoa-Hueso 2023).

Water Management and Energy Efficiency and other Climate-Smart Practises

Given horticulture's vulnerability to varying climatic conditions, especially deciduous fruit in the Western Cape, HortGro, together with the Western Cape Government and Blue North consultancy produced a Climate Change Response Strategy for Deciduous Fruit Industry in South Africa (Midgley et al. 2022). While soil health is fundamental to this strategy, it also suggests adaption strategies such as water efficiency through improved irrigation systems and precision scheduling, sustainable cultivar choices to mitigation options such as alternative energy supplies and improved resource and energy efficiency.

The adoption of industry platforms such as the Confronting Climate Change Initiative is not only beneficial for the environment but also provide farmers with significant cost savings. For example, by installing solar panels, they not only reduce their carbon emissions but also reducing their reliance on the national electricity grid and the increasing electricity tariffs. Case studies have shown that optimising water management leads to significant reduction in water consumption and this translates into cost savings too. It also means that farmers are meeting consumers' demands given the growing awareness of "food miles" and the need to know the granular details of the sector's carbon footprint. Blignaut explains that South Africa is a leader in this field as "there is no other country with comparable industry-wide project to calculate carbon footprints" (Mouton 2022b).

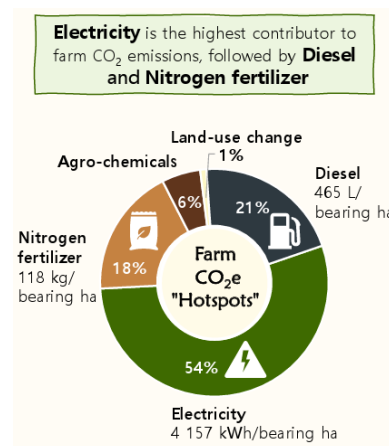


Figure 9.3 Carbon Calculator by CCC Initiative Benchmark Report 2022 for Pome Fruit.

Source: Wessels (2022)

9.5 Financial costs

Cover Crops

Literature shows possible trade-offs between cover cropping and crop productivity. A study taking place within vineyards suggested that that cover crops compete for soil resources such as water and

nutrients, resulting in a decrease in yield (Ochoa-Hueso 2023). However, the scale and intensity of this depends on various factors – soil depth and fertility, rainfall/irrigation and fertilisation regimes. Other studies reveal positive effects on yield (Messiga et al. 2016 in O'Brian et al. 2025), while further studies show no effect (Cabrera-Pérez et al. 2023 in O'Brian et al. 2025).

A study showed that in areas with fertile soils and high precipitation rates, the competition of cover crops under-trellis reduced the vegetation growth, resulting in a reduced canopy and pruning weight and during dry seasons which led to a significant reduction in grape yields (Bernaschina et al. 2023). A study which measured the vine canopy wine use efficiency (WUE) reveals the potential risk of growing cover crops in arid areas that encounter water shortages as the study showed decreasing WUE with increased competition from cover crops (O'Brian et al. 2025).

However, some of the advantages of reduced vegetation growth and canopy size showed an increase in the fruit Brix (the measurement of sugar content) and anthocyanin (natural pigments¹⁷) concentrations and in the wines, there was an increase in overall aroma intensity. Furthermore, aerated canopies and less compacted bunches were associated with lower incidence of bunch rot (BBR) (Bernaschina et al. 2023).

Another study show that for perennial, high-value crops, excessive nitrogen in soils may lead to poorer fruit quality due to the increased mineralisation rate of soil organic matter (Swanepoel 2021).

The type of cover crop or mulch will be dependent on the climate, crop type, soil properties and the needs or purpose of the producer and management practices. It is important to note that practices tailored to specific contexts are crucial, and no single climate smart practice can be universally recommended to address issues in orchards and vineyards (Swanepoel 2021). It is important that water demand and availability are considered when selecting cover crops for a vineyard (crops (O'Brian et al. 2025).

Chemical inputs

For many farmers, chemical control is often the primary defence strategy due to its immediacy and effectiveness in reducing pest populations and other diseases. Insect pests and other diseases continue to affect agricultural production, which impact the yield and quality of South Africa's horticultural produce.

Furthermore, to export certain produce, a phytosanitary certificate is needed which guarantees that the produce is free from quarantine pests and practically free from other pests. This to prevent the risk of spreading harmful organisms to other countries and as a result pesticides and herbicides are used to meet these standards (CBI Ministry of Foreign Affairs). Given how much of the fruit production is driven by the export market, these are important considerations.

There are also strict maximum residue levels (MRLs) set by the countries and producers must comply with export requirements by responsibly and correctly using pesticides, and by accurately measuring and monitoring pesticide residues according to international standards (Quinn et al. 2011).

It is therefore a fine balance between implementing CSRA practices and meeting overseas market requirements, which is fundamental to much horticultural production.

While they are many benefits of implementing IPM, switching to IPM is considered a big risk and it step that is not cheap. There are higher input costs as the registered biochemicals are not always cheaper than conventional methods and there are limits to available product choice. The bioproducts are not always as effective as the conventional harsher sprays and therefore adopting IPM needs to

¹⁷ Naturally occurring pigments that possess antioxidant properties.

be views with a long-term perspective. Addison explains further that the benefits and cost-savings of not spraying chemicals are not immediate but rather accrue over time (Steenkamp 2021b).

Livestock integration

The discussion above explained that livestock integration is generally introduced during the winter months. For integration of livestock all year round, structural modification of the vineyard to raise the trellis system needs to take place and this will impose costs.

Water management and energy efficient technologies

Implementing renewable energy solutions and water efficiency applications, reduces long-term environmental impacts and long-term costs, but have high upfront costs. Adopting greenhouse technology or precision agriculture tools involves substantial expenditures on sensors, automation and monitoring systems. Financial institutions may also hesitate to provide loans due to the perceived risks of innovative or non-traditional practices.

9.6 Social benefits

Healthier, more nutritious food

The reduction in harmful chemicals has social benefits since it reduces exposure to harmful pesticides to farm workers and other personnel. HortGro's Addison explains the main benefit of IPM is the avoidance of hard chemicals: "There are obvious health benefits all round, not only for humans but also for the environment. A more sustainable ecosystem with healthier soil and less groundwater contamination" (Steenkamp 2021b).

CSRA is aimed at producing fruit and vegetables that are wholesome and nutritious. According to Jones (2018), soil health affects human and animal health since the level of nutrients in almost all our foods has fallen by 10–100%. According to a study by Dr David Thomas published by the Medical Research Council Ministry of Agriculture, Fisheries and Foods and the Food Standards Agency, there has been a severe depletion of mineral and trace element content in every food group investigated (Jones 2018). CSRA focuses on restoring soil health to have an array of soil microbes which means the soil then has the ability to support nutrient dense, high vitality crops, fruit and vegetables.

Information and knowledge sharing

Given the definition in Chapter 2 that *"CSRA is a principle-based agricultural and transdisciplinary systems approach that integrates local and indigenous knowledge of landscapes, as well as their management, with established scientific knowledge,"* the adoption of CSRA provides opportunities for information and knowledge sharing.

Three examples of this positive information sharing opportunities are described as follows:

Community workshops

After the 2003–2006 drought where rooibos farmers in the Bokkeveld area lost 40–100% of their cultivated rooibos crop, farmers in the Heiveld Co-operative initiated quarterly climate change preparedness meetings. Meetings were held to discuss and learn and provide a forum to share information on climate, farming and the interaction between the two, e.g.:

- observations on rainfall and temperature fluctuations
- incidences of pest infestations
- weight and condition of livestock
- differences in ploughing techniques
- responses to wind erosion and a host of other topics

These workshops enhanced farmer's knowledge and provided them with ideas and tools to respond to climate change after devising their own strategies on how to respond to projected weather changes. Four scientific weather stations were established in the Suid Bokkeveld to complement and triangulate local weather data collected by community members, creating a baseline for future climate change discussions and planning (UNDP 2015).

Furthermore, the Heiveld Co-operative contributed towards sustainable land management by formulating guidelines for the harvesting of wild rooibos and drawing on traditional knowledge of the community (UNDP 2015).

HortGro's app

The HortGro's app for pome and stone fruit growers is based on the premise that growers need reliable science-based source of information to guide their decision-making, and this should differentiate between different production regions with different climate characteristics. The objective is to compile a science-based, relevant and practical guide (practitioners' handbook) to pome and stone fruit farmers in South Africa on climate change risks, impacts and adaptation responses (<https://climatechange.hortgro.science/>).

Participatory Guarantee System (PGS)

IFOAM – Organics International describes the Participatory Guarantee Systems (PGS) as “locally focused quality assurance systems. They certify producers based on active participation of stakeholders and are built on a foundation of trust, social networks and knowledge exchange” (PGSSA website).

Participants of the PGS, says that PGS provides more than just access and market credibility for their organic sales. Instead, it has important social dynamics as it brings together farmers from across the spectrum – some new developmental and small-scale farmers to large-scale commercial farmers. It has become a learning channel. There is a peer-to-peer review of the practices on the farm as well

as a skills and practice sharing. A members described it as an “experimental farming laboratory”, where they leverage off each other’s knowledge and apply it on the ground (CARI 2022).

9.7 Social costs

Information sharing forums and knowledge sharing platforms require funding and often donor support. Ensuring accessibility is always a challenge.



Part D

INSTITUTIONAL ANALYSIS

Chapter 10 Overview and importance of South Africa–Netherlands bilateral collaboration in agriculture

10.1 Historical overview of the relationship in agriculture between South Africa and the Netherlands

The agricultural relationship between South Africa (SA) and the Netherlands dates to the early 17th century. South Africa and the Netherlands are two countries with robust agricultural sectors that play significant roles in the global food system. Despite differing geographical and environmental conditions, their agricultural and horticultural landscapes share many points of convergence, especially in areas such as innovation, sustainability and the pursuit of food security (Vink & Kristen 2003).

The two countries have a long history of agricultural exchange, driven by the Dutch influence on SA's farming techniques, practices and the establishment of agricultural trade. These included techniques such as cultivation of wheat, vegetables and the use of advanced irrigation systems, among others. The most notable exchange at the time was in viticulture where the Netherlands was heavily involved in the SA wine industry (Van Zyl 1987). The Dutch have maintained commercial relations with SA for many decades through continuous mutual economic interest benefiting trade in agriculture. They have also provided expertise in areas such as dairy farming and vegetable production, particularly through the provision of equipment and technology. They played a role in improving irrigation techniques, which helped South African farmers in arid regions improve yields and efficiency (Van Rooyen et al. 2017). The Netherlands, known for its agricultural innovation, became a valuable partner in helping South Africa modernise its farming practices. Dutch technology, particularly in greenhouse farming, precision agriculture and irrigation systems, played a key role in transforming South African agriculture (Van Eck et al. 2017; Pross 2020). Moreover, the Netherlands became one of South Africa's largest trading partners within the EU, with agricultural products such as fruit, wine and flowers forming the backbone of bilateral trade (European Commission 2023; Export Focus Africa 2024).

Various trade agreements exist between the two countries that foster deeper collaboration in agriculture. These agreements focus on sharing knowledge on sustainable farming practices, advancing climate-resilient agriculture, and enhancing market access for South African agricultural products in Europe. Today, the South Africa–Netherlands agricultural partnership is a model of international cooperation, demonstrating the power of shared knowledge and innovation in agriculture (Government of the Netherlands 2023). Both countries benefit from this collaboration, with the Netherlands continuing to support South Africa in achieving agricultural excellence while also gaining access to high-quality South African agricultural products.

10.2 Agricultural and horticultural landscape of South Africa and the Netherlands

South Africa has a diverse agricultural industry that is characterised by a wide range of crops and livestock products, including fruits, vegetables and wine, among others. Not only does it form a critical part of the country's economy and consumption, but it is also one of the leading exporters of agricultural products in Africa (Sandrey et al. 2011; Mlambo et al. 2019; Seti & Mazwane 2024). South

Africa's agricultural exports primarily target the EU, the Middle East, Asia and the US. The Netherlands plays a central role as a key gateway to European markets particularly in Africa's wine and fresh fruit industries. While it is a success, the South African agricultural sector faces challenges such as high costs of production inputs, degraded soils, water scarcity, climate change and variability, long-term sustained yields, pests and diseases, as well as technological modernisation and innovation limitations, among others (DAFF 2020a). These challenges affect the growth and advancement of the overall sector.

While the Netherlands has a relatively small land area, it has emerged a global leader in agriculture; known for its technological advancement, high output farming and agricultural innovation in greenhouse farming and precision agriculture (Whiting 2019). These advancements have also allowed farmers to grow crops in controlled environments, reducing reliance on natural resources such as water and arable lands. They have also inspired an agricultural reality where data and technology can be used to optimise farming practices, improve efficiency and reduce waste. Making the Dutch agricultural sector more sustainable and resource-efficient with minimised environmental impacts. Not only has these strengths of agricultural sector made them capable of feeding a growing nation but these also contribute to the feeding of a global population. The Netherlands is one of the world's largest agricultural exporters of dairy products, vegetables and flowers (WTO 2020; Statistics Netherlands 2024).

Both South Africa and the Netherlands face similar agricultural challenges, despite their distinct environments with the main concern being climate change led. Both countries are vulnerable to shifting weather patterns, with South Africa experiencing increased droughts and the Netherlands facing the threat of rising sea levels (Masipa 2017; DAFF 2020a; Bonetti et al. 2022; Wageningen University & Research 2024). As such, both nations are focused on developing climate-resilient agricultural practices, such as drought-resistant crops, more efficient water management systems, sustainable agricultural practices, and ensuring a stable and reliable food supply. These issues show that, while the agricultural landscapes of South Africa and the Netherlands are distinct yet interconnected, both countries can bring their strengths in collaborations and advance mutual goals. Thereby strengthen both agricultural systems and contribute to global food security.

10.3 Key areas of collaboration

South Africa and the Netherlands have shared commitment towards innovation, sustainability and improving agricultural practices. The South Africa–Netherlands agriculture and horticulture collaborations are driven by mutual benefits and designed to address pressing challenges such as food security, water scarcity and climate change, while ensuring the sustainability of agriculture in both countries (FAO and World Bank 2018; Stringer et al. 2019; South African Government 2020; Bosmans 2024; Netherlands Ministry of Foreign Affairs 2024). The different strengths of each country are complementary and can help ensure success for both. Table 10.1 shows the significant areas of agriculture collaboration between the two countries and how each is facilitated.

Table 10.1 Significant areas of collaboration between South Africa and the Netherlands

Focus area	Netherlands		South Africa	
	Strengths	Benefit flows to SA	Strengths	Benefits flow to the Dutch
Technology and innovation transfer	Precision farming, smart agriculture, advanced technologies and high-level data analytics.	Enable data-driven decisions, optimising irrigation, fertilisation and pest control. Improve farming efficiency, reduce resource waste and increase yields. Monitor crop health and soil conditions.	Broad crop variety, agricultural biodiversity, extensive experience in cultivating crops under diverse climatic conditions.	Provides valuable data and insights into crop adaptation and environmental resilience. Adapt technologies to a wider crop range and improve agricultural systems.
Water management and irrigation systems	Knowledge of managing water resources in a water-abundant and population dense country (drip irrigation techniques, rainwater harvesting technologies, and smart irrigation systems).	Water use efficiency and redirection to crop root systems. Water conservation, improved crop yields and reduced the environmental impact of agricultural practices.	Experience in large-scale irrigation systems and major efforts in developing innovative irrigation infrastructure in arid and semi-arid regions.	Valuable insights into water resources management in countries with varying levels of water availability. Inform strategies for sustainable water use.
Climate change adaptation and sustainability	Successful in sustainable agriculture techniques, organic techniques and crop diversification.	Adoption to climate pressures (unpredictable rainfalls and extreme temperatures). Enhanced soil fertility. Reduced reliance on chemicals.	Successful in climate smart practices (climate smart irrigation) and climate-resilient crops (drought-tolerant maize varieties). Practical approach to mitigating effect of climate extremes.	Knowledge transfer on CA/RA and climate resilience. Expertise on coping with dryland farming regions and growing climate resilient crops. Aid research into the impact of climate change on crops and enhance implementation of adaptive strategies.
Training and capacity building	Provision of training, technical education and scholarships.	Transfer of knowledge, skill, and technical capacity to farmers and agricultural professionals.	Knowledge of local agriculture conditions. Extensive on ground farmer network. A diverse agro-ecosystem.	Knowledge and skill transfer to farmers and agricultural professionals. Better understanding of small-scale farming practices. Valuable data crop resilience and insight into new farming techniques and systems.

Sources: Mitchell (2011); OECD (2015); Say et al. (2017); Stringer et al. (2019); South African Government (2020); Dutch Embassy in Pretoria (2021); Netherlands and You (2021); Netherlands Water Partnership (2021); Dutch Embassy in Pretoria (2022); DSTI (2023); Bosmans (2024)

10.4 Bilateral agreements

South Africa and the Netherlands have a wide range of bilateral agreements in areas of trade, economic and development co-operations; science, technology and innovation; education and training; environmental protection and climate change; and agriculture and horticulture (South African Government 2015, 2020; DIRCO 2023; Agroberichten Buitenland 2023; Embassy of the Kingdom of the Netherlands 2023). The collaboration between South Africa and the Netherlands in agriculture has been formalised through various trade agreements, memorandums of understanding (MOUs) and other joint initiatives such as the 2023 Water Managements and Sanitation MoU and the 2022/2023 Science, Innovation, and Education MoU, among others. They are driven by the EU, Dutch government

and South African government. These agreements have allowed both countries to establish frameworks for cooperation, including areas such as agricultural trade, technology transfer and sustainability efforts, among others. The success of these partnerships demonstrates how effective international cooperation can address shared global challenges and create opportunities for economic growth and food security. Table 10.2 highlights some key agreements.

Those most relevant to climate smart regenerative agriculture (CSRA) can be found mostly in those such as: Agri-Tech Innovation Agreements, SA–Netherlands Innovation Partnerships in Agriculture, Dutch–South African Partnerships in CSRA, Water Management Initiatives. These are focused on CSRA partnerships, agricultural innovation and technology, water management, sustainable development and climate change. Others are indirectly involved in that they enable market, trade and investment opportunities for climate resilient although not specifically CSRA.

Table 10.2 *Agriculture and horticulture bilateral agreements between South Africa, the Netherlands and EU*

<i>Category</i>	<i>Programme</i>	<i>Role</i>	<i>Relevance to climate smart regenerative agriculture (CSRA)</i>
EU-SA	EU-South Africa Trade, Development, and Cooperation Agreement (TDCA)	To strengthen political, economic, and trade relations between the EU and South Africa.	It is not directly involved but can support CSRA through provision of agricultural trade landscape including climate smart practices and technologies.
	EU-South Africa Partnership and Cooperation Agreement (PCA)	To enhance cooperation in various fields, including political dialogue, economic cooperation, and sector-specific initiatives.	It is not directly involved, however its broader scope of focus on sustainable development includes support to initiatives that are aligned with CSRA practices, especially on environmental sustainability, agricultural development and climate resilience.
	South Africa-Netherlands Agricultural Cooperation Agreement	To facilitate bilateral cooperation in the agricultural sector.	It is relevant to CSRA through collaborations on agricultural practices, innovations and knowledge transfer. It includes the Bilateral Committee on Agriculture (CoA) which identified CSRA among its priority topics.
SA-Netherlands/Dutch	SA-Netherlands Innovation Partnerships in Agriculture	To promote innovation in agriculture between South Africa and the Netherlands.	It is directly relevant to CSRA through its focus on agricultural technology innovation including climate smart technologies. These include the 2022 Innovation Missions on Climate-Smart Agriculture, and the 2023 Centre of Vocational Excellence (CoVE) for Climate-Smart Agriculture, among others.
	South Africa-Netherlands Food Security Initiatives	To ensure food security through bilateral cooperation.	It is relevant to CSRA as its focus on sustainable food systems are tied with climate-resilient agricultural practices. Included are project like the Climate-Smart Horticulture and Just Energy Transition
	South Africa-Dutch Water Management Cooperation	To target water management and environmental sustainability.	Projects like the Blue Deal Programme relevant to CSRA through its focus on addressing water resource management in agriculture to ensure conservation and efficient use of water.

South Africa-Dutch Bilateral Trade and Investment Agreements	To promote trade and investment between South Africa and the Netherlands.	It is not directly relevant unless if investments are directly allocated to sustainable agricultural practices that align with CSRA principles.
Dutch Private Sector Investment Agreements	To attract Dutch private sector investment in South Africa.	It is not directly relevant unless where there is a focus on private-sector involvement in CSRA such as the Climate-Smart Horticulture Demo Facility at Grootvlei, and the Smart Adaptive Sustainable Horticulture (SMART) Programme.
Horizon 2020 and Horizon Europe Collaboration	To promote research and innovation.	It is involved through programmes funded towards CSRA such as the LEAP-AGRI.
Agri-Tech Innovation Agreements	To promote technological innovations in the agricultural sector.	It is involved through its support towards the development and implementation of climate smart technologies such as through the Water Efficient Maize for Africa (WEMA) Project and the Innovation Missions and Collaborative Workshops.
South Africa-Netherlands Knowledge Ecosystem	To foster knowledge sharing and collaboration in science, technology, and innovation.	It is involved where CSRA is supported through knowledge exchange on sustainable agricultural practices and climate change adaptation strategies in agriculture. An example is of the Centres of Vocational Excellence (CoVE) in Climate-Smart Agriculture.
Sustainable Development Cooperation Framework (SDCF)	To target sustainable development.	It is relevant to CSRA through its promotion of sustainable development goals (SDGs), climate action and resource management.
Dutch-South African Partnerships in CSRA	To focus on addressing climate change in the agricultural sector.	It is solely focused on CSRA by promoting climate-resilient agricultural practices through Centres of Vocational Excellence (CoVE), innovation missions and other projects.

Dutch-South African Water Management Initiatives	To strengthen cooperation on water resource management.	It is relevant as it addresses the sustainable use of water resource in agriculture which is a key component of CSRA.
Dutch Trade Missions to South Africa	To facilitate trade and investment missions from the Netherlands to South Africa.	It is not directly involved however there is an opportunity to support CSRA through market expansion for CSRA technologies or produce in line with economic missions, collaborations and sector engagements.
Hortipreneurial Centre of Excellence	To promote horticultural innovation and entrepreneurship.	It is not directly involved however there is an opportunity to support CSRA through the promotion of climate smart horticultural techniques.
Inclusive Agricultural Business Partnerships	To promote inclusive business partnerships in the agricultural sector.	It is directly involved through its focus on inclusive business practices that can support smallholder farmers to CSRA practices and climate-resilient agricultural value chains.

10.5 Dutch investments in South Africa's agricultural sector

The agricultural sector in South Africa has significantly benefited from Dutch investments, which have helped modernise farming practices, improve infrastructure and drive technological innovation. Dutch foreign direct investment (FDI) has played a crucial role in revitalising South Africa's agricultural and horticultural industries by supporting both public infrastructure projects and private-sector partnerships. In 2022, the Netherlands accounted for 36.7% of South Africa's total inward FDI stock, making it the largest single investor in the country (Trade.mu 2023). These investment benefit flows are as shown in Figure 10.1 (Netherlands Enterprise Agency 2023; DTIC 2023; WUR 2023; Van der Merwe et al. 2023). These investments have not only benefited South African farmers but have also contributed to job creation, economic growth and food security in the country. Moving forward, the continued partnership between Dutch investors and South African stakeholders will be crucial in addressing ongoing challenges such as climate change, water scarcity, market access, biodiversity preservation, reverse export flows and opportunities, and others.

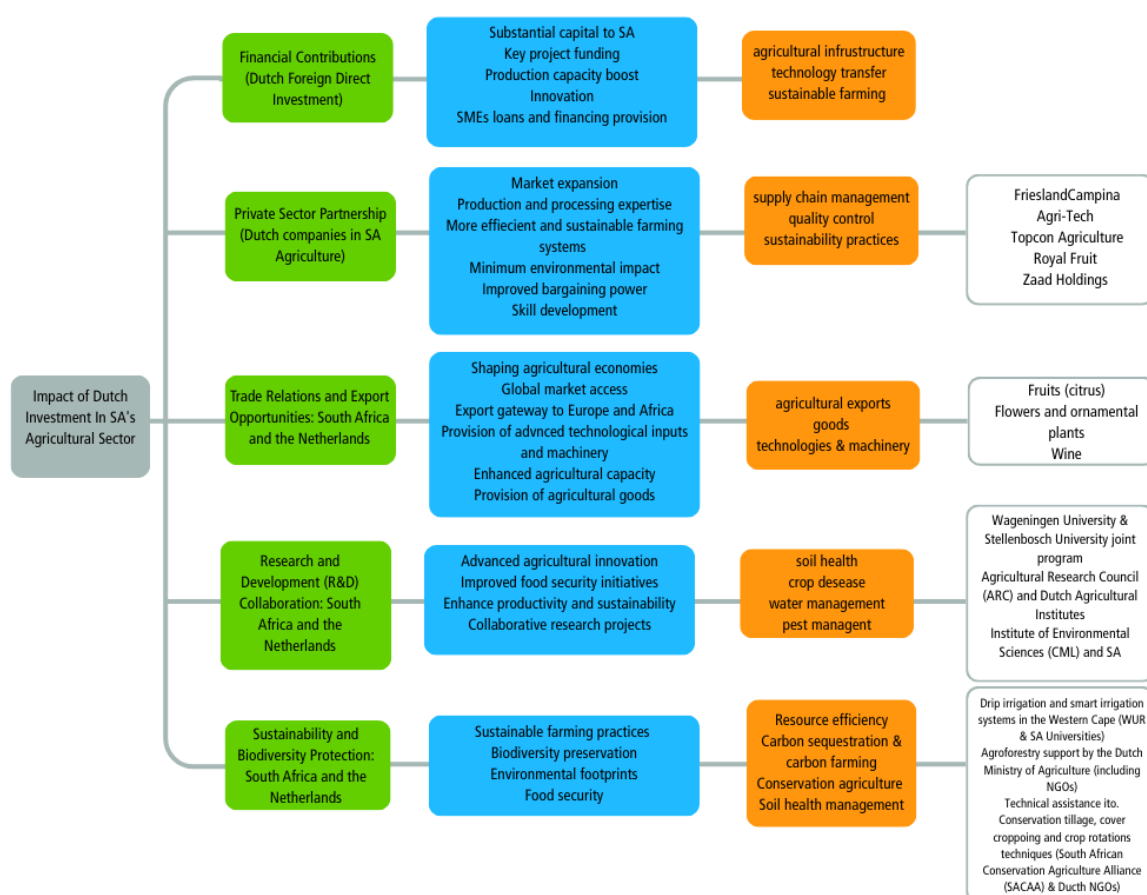


Figure 10.1 Dutch investments in South African agricultural sector

10.6 Future prospects and opportunities

The dual challenge of increasing food production while minimising the environmental impact of the agricultural sector poses a unique but vital challenge in history. This dilemma, however, is filled with immense opportunities for future collaboration in emerging fields such as, but not limited to, urban agriculture, vertical farming, sustainable energy solutions, efficient water management, organic

farming produce demand, agro-processing and biological products. South Africa and the Netherlands can leverage their strengths to shape the future of their agricultural sectors by expanding cooperation in the following areas (FAO 2010; Netherlands Enterprise Agency (RVO) 2023; Bosmans 2024):

- **Sustainable agricultural practices and regenerative agriculture**
 - Severe water scarcity issues in South Africa pose a great threat to its agricultural sector.
 - Netherlands has expertise in efficient water use management and irrigation systems.
 - Collaboration aimed at sustainable farming practices can mitigate water use inefficiency and promote soil water holding capacity, health and fertility.
 - Such can help domestic farmers improve yields while minimising environmental impact and achieving sustainable food production and climate change resilience.
- **Vertical farming and urban agriculture**
 - Fast growing solution to increasing food production in urban areas while saving water consumption and minimising land use.
 - Netherlands has expertise in hydroponics and aeroponics. SA is facing rapid urbanisation, water scarcity and land degradation; which provides opportunity for collaboration.
 - This can enhance food security and support the fresh produce market.
 - Collaboration can focus on establishing urban farming hubs in South Africa while leveraging on Netherlands' expertise in hydroponics and aquaponics.
 - This can expand the agri-tech and innovation collaboration between the two countries.
- **Sustainable energy solutions in agriculture**
 - There is a growing need to find cleaner, more sustainable energy solutions for the future of farming.
 - Netherlands is at the forefront of renewable energy, smart grids, energy-efficient farming technologies and sustainable agricultural practices. SA needs to reduce severe greenhouse gas emissions and reliance on fossil fuels to minimise the impact of farming footprints.
 - Collaboration can focus on integrating solar-powered irrigation systems, expanding research on waste-to-energy solutions and bioenergy.
- **Agro-processing and value addition**
 - The agro-processing sector is of essential value to the overall SA economy as it not only adds value to agricultural products but stimulates overall economic growth while addressing socio-economic interest.
 - The Netherlands is a global leader in efficient and sustainable agro-processing technologies and systems. While SA has a strong agricultural base, the development of its agro-processing sector is not as strong.
 - Collaboration opportunities exist in the processing, packaging and preservation of plant-based products, fruits, vegetables and dairy.
 - Such can aid efficient logistics and supply chain solutions in South Africa and provide a large-scale opportunity for other joint ventures and investments.
- **Research and education partnerships**
 - Research and education are a key focus area of collaboration and investment between South Africa and the Netherlands.
 - Agricultural institutions and universities can collaborate in a pool of various joint research initiatives and programmes.
 - Such can advance skill development for different role players in the sector.

- **Youth participation in agriculture**

- The inclusion of youth in agriculture is essential not only for the future of agriculture but also to ensure food security, economic growth, and sustainable development in South Africa.
- The Netherlands has a strong base and ability to provide skill development or co-fund various agriculture related opportunities.
- Collaboration can take place also through vocational training programmes, mentoring opportunities, agri-entrepreneurship in agro-technology, digital agriculture and sustainable farming. A good existing example is that of the Netherlands Agrarisch Jongeren Kontakt (NAJK) and AgriYouth without Borders (AYWB) (Agroberichten Buitenland 2024).

The future prospects for South Africa-Netherlands collaboration in agriculture are incredibly promising. Both countries stand to benefit from deeper partnerships in emerging agricultural sectors which align with global trends toward sustainability and environmental responsibility. By leveraging on the Dutch expertise, SA can address critical challenges such as water scarcity, climate resilience and unemployment, among others. The Dutch can leverage on SA's diverse climate zone and offering, large-scale production expertise, indigenous crop knowledge, emerging agro-processing production opportunities and many others. Dutch agricultural technology and climate-smart solutions can be tested and adapted across different agro-ecological zones; partnership with local producers to scale indigenous and underutilised crops with export potential; and co-investing in agro-processing value chains to enhance beneficiation and increased export readiness of products, among others opportunities to be explored in the next chapter.

10.7 Challenges and obstacles to collaboration

While both countries share common goals, such as improving food security, promoting sustainable farming and enhancing agricultural productivity, collaboration is still faced with a range of challenges and obstacles that have slowed or hindered its full potential. These challenges are mainly political and economic as well as logistical and cultural, explored in Figure 10.2 (Vink 2000; Mpandeli and Maponya 2014; Davis and Terblanche 2016; Von Loeper et al. 2016; Masipa 2017; DAFF 2020b; Netherlands Water Partnership 2021; ARC 2021; Bosmans 2024).

These challenges may cause varied degrees of hesitation in the Dutch stakeholders, institution and value chain. For example, Dutch companies and organisations invested in SA's agricultural sector may become increasingly hesitant as political challenges may cause changes in the agricultural investments and slow down implementation of projects. Similarly, economic challenges may cause hesitation as ensuring that Dutch collaborations reach a broad scope of those who need them can be difficult due to the uneven distribution of resources, capital and infrastructure across South Africa. The volatile exchange rate may, for Dutch investors, present risks that could impact their returns on investments in South Africa's agricultural sector. Additional challenges may also occur in trying to implement advanced farming techniques in rural areas where infrastructure limitations exist. Thus, despite shared objectives in productivity, sustainability, food security and collaborations between South Africa and the Netherlands, there are some hurdles that both countries face. Economic and political disparities and inconsistencies, inadequate infrastructure and relatively poor technological uptake pose significant challenges to the agricultural sector collaborations. These, however, can be addressed through inclusive economic strategies, risk mitigation initiatives, stable policy framework development

and other at a collaborative level. Strengthening collaboration in challenge-stricken areas can be severely beneficial and provide ample opportunities

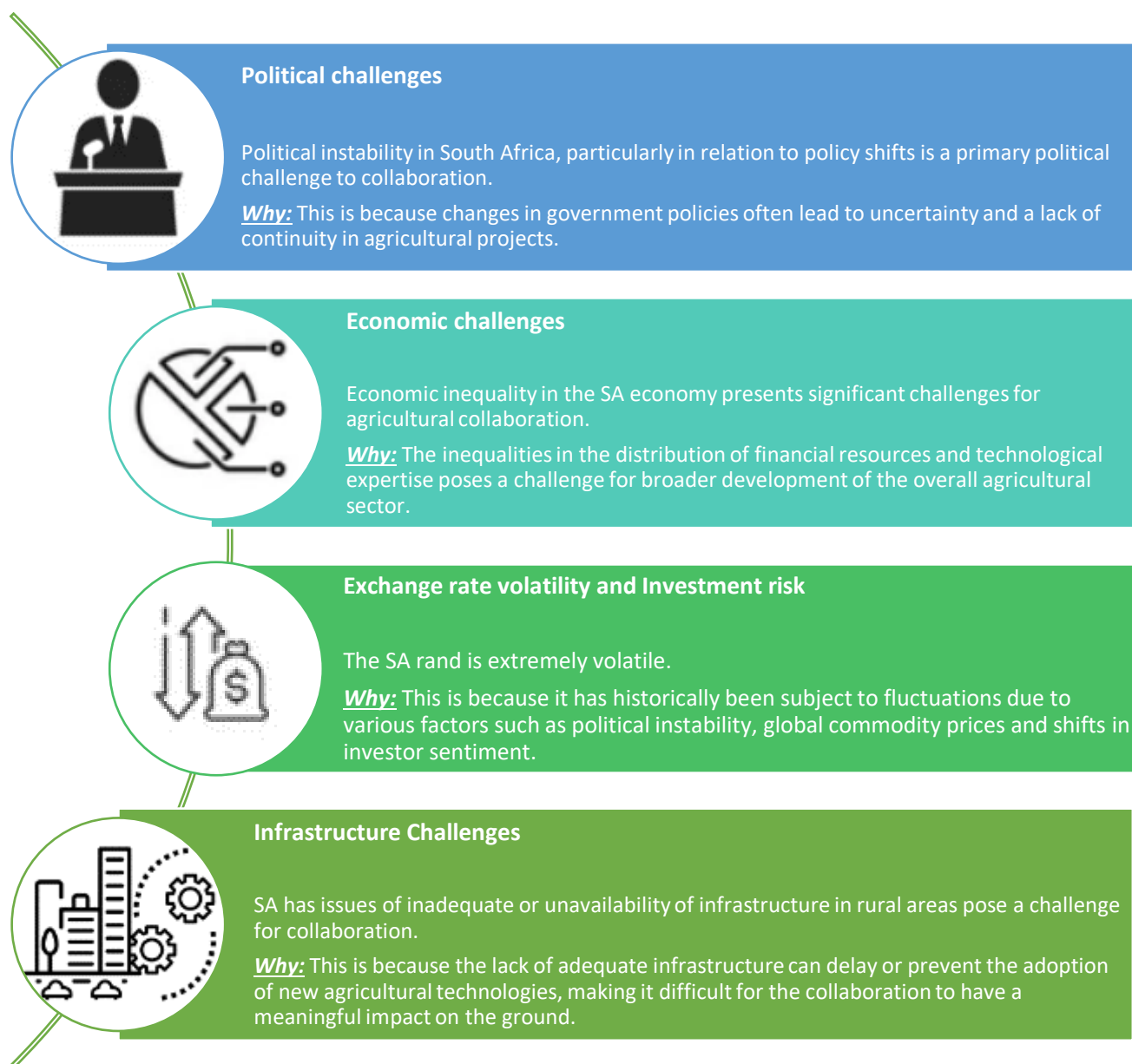


Figure 10.2 Challenges and obstacles in the Dutch-South African collaboration

10.8 Key stakeholder identification, roles and interest mapping

The agricultural and horticultural collaboration in SA includes an assorted group of institutions, stakeholders and value chain actors such as government bodies, research institutions and NGOs, financial institutions, farmers and producers, among others. This multi-faceted approach helps in managing, administrating and expanding the sector while also facilitating collaboration and ensuring successful resource flow, value chain and bilateral agreements. Annexure 7 classify their involvement

and highlights that most of the institutions and stakeholder groups are in the primary level of involvement indicating direct involvement which highlights a strong and active participation. Figure 10.3 shows the roles of stakeholder groups and highlights existing linkages. Four key observations can be made from the figure which are: (1) while there are four key stakeholder and institutions roles, majority play a market role, (2) research institutions have an overlapping market and regulatory role, (3) NGOs have an overlapping market and political role, and (4) government agencies have an overlapping political and regulatory role. Depending on existing opportunities and desired level of collaboration, these roles are essential in understanding the goals and motivations of each stakeholder and what drives them, and how they can be incorporated in future. They also aid in better decision making, efficient resource allocation, proper monitoring and evaluation, and effective collaboration and opportunity maximisation.

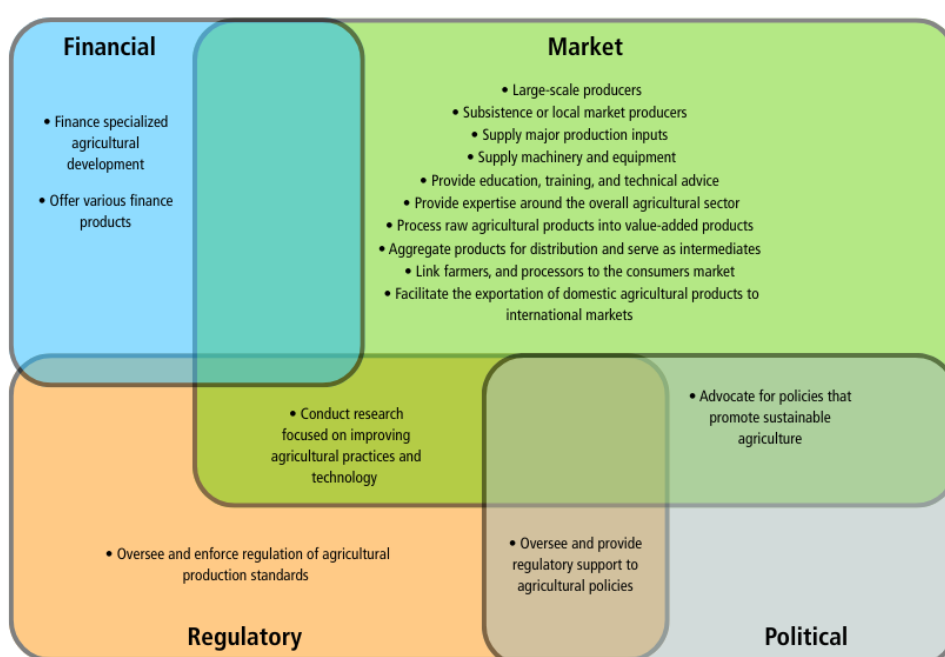


Figure 10.3 Institutional and stakeholder roles

In addition to understanding the roles of institutions and stakeholders, each have a specific set of interests (see Annexure 7) that are economic (cost reduction, profit maximisation and financial sustainability); social (social development, empowerment, financing and wellbeing); environment (climate change mitigation, natural resource and biodiversity conservation and sustainability), and/or political (policy advocacy and implementation, public interest, influence and food security). Table 10.3 shows interests that can be identified to each category. Of these stakeholder and institutions categories, Figure 10.3 shows that:

- All stakeholder, institutions and value chain actors have an economic interest that include lowering production input costs, improving profitability, expanding market share, fair pricing, managing financial risk and many others.
- A great majority also have an environmental interest that include factors such as building climate resilience, ensuring sustainability, reducing environmental impact, encouraging the adoption of sustainable agricultural practices and ensuring food security.
- Most social interest is around promoting knowledge transfer, improving market access for farmers, reducing poverty and inequality and supporting local economic growth.

- Political interest is aided more towards promoting agricultural exports through policy support, ensuring international trade and compliance, and policy development.

These interests are greatly linked to some of the benefits of implementing CSRA principles (see case studies in previous chapters). As such, it can be inferred that CSRA is a best-case solution for various stakeholder interest and motivations.

Table 10.3 *Key interest that drive the motivations and goals of each stakeholder/institution category*

Category	Sub-category	Key interests
Farmers and producers	Commercial farmers	Maximising yields, lowering production input costs, improving profitability, maintaining competitiveness, expanding local and international market access, advancing farming technology and practices, ensuring sustainability.
	Smallholder and emerging farmers	Improving productivity and income, market access, financing, better technology and farming practices, building climate resilience.
Input suppliers	Seed and major production input suppliers	Product uptake, maximising sales, expanding market share, maintaining compliance with policy and regulations, promoting farming techniques.
	Machinery and equipment suppliers	Market expansion for mechanisation, provision of new technologies that can help farmers optimise their scarce resources (land and water) and efficiency and scaling.
Service providers	Extension services and agricultural advisors	Enhancing farmer capacity, promoting knowledge transfer, encourage the adoption of sustainable agricultural practices including CA/RA.
	Consultants and research institutions	Sustainability and productivity aiding research, policy development, knowledge and insights dissemination to farmers and the sector at large.
Processors and agri-businesses	Food and beverage processors	Securing their sourcing channels, building consistent and reliable supply of products from farmers, expanding market access, maximising profits.
	Cooperatives and small-scale processors	Improve market access and fair pricing for smallholder farmers, enhancing value-added product offerings and supporting local economic growth.
Distributors and traders	Wholesalers and retailers	Creating and expanding market share local and international market, maximising profits, ensuring efficient supply chain and product availability, maintaining product quality consistency.
	Exporters and international traders	Strong foreign market relations, good product specification and standards, increasing competitiveness of SA agri-products globally, expanding the foreign market, identifying new export opportunities.
Financial institutions	Development finance institutions (DFIs)	Transformation in agriculture dynamics and infrastructure, promoting rural development and focused projects, and reducing poverty and inequality.
	Commercial banks	Maximising profit, expanding agricultural clientele and managing financial risk.
Government and regulatory bodies	Government ministries	Promoting sustainable and resilient agricultural sector, ensuring food security, improving market access for farmers, promoting agricultural exports, <u>financing</u> and incentivising sustainable practices.
	Regulatory agencies	Promoting food safety, ensuring international trade requirements are met to maintain market access, and ensuring compliance with existing standards.
Research institutions and NGOs	Agricultural research institutions	Improving agricultural productivity through advancing scientific knowledge, addressing emerging challenges through innovative research and technology development, and collaborating with various stakeholders for implementation.

	Non-governmental organisations (NGOs)	Advocating for policies that prioritise development, equality, empowerment and sustainability.
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Sources: Kristen and Van Zyl (1998); Coetzee et al. (2002); Esterhuizen (2006); Ramabulana (2011); Sims et al. (2012); Wilk et al. (2013); Mpandeli and Maponya (2014); Raidimi and Kabiti (2017); Zwane and Davis (2017)

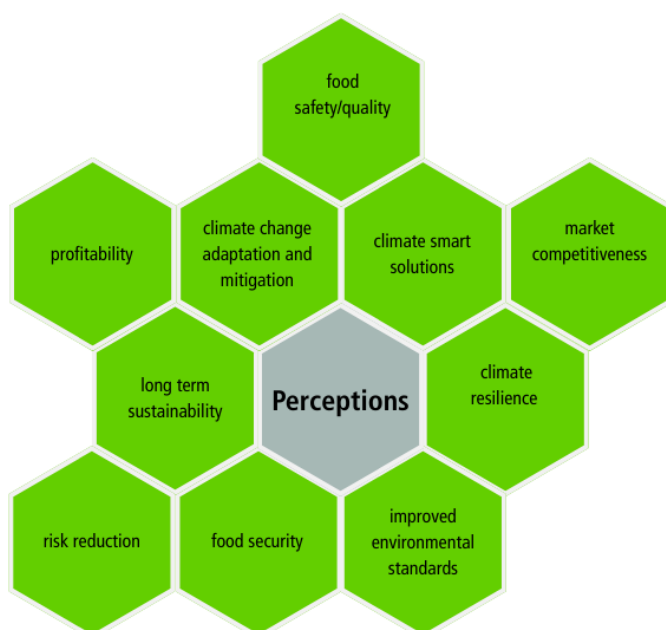
10.9 Interest, influence and engagement analysis

Although the success of the agricultural sector is led by institutions, stakeholders and value chain actors that have different roles and interests, it is important to understand the influence that each have. By identifying key influencers, understanding their motivations and predicting how their influence will affect outcomes, organisations can make more strategic, informed decisions, manage risks, allocate resources effectively, and ultimately achieve their goals. This is influence in terms of who holds the highest, moderate and least power to influence decision-making processes and outcomes. Commercial farmers, seed and major input suppliers, government, wholesalers and retailers, and exports and international traders have the highest interest and influence. For farmers, this may be due to their significant share of decision making in the SA agricultural output and export (Vink 2000, 2004). Input suppliers may be due to their influence on the productivity, sustainability and innovative capacity of their products; in which they can drive and intensify sector-wide trends and adoption of varieties, techniques and ultimately farming practices (Ortman & King 2010). The relevant government ministries are influential in that their decisions shape market regulation, access, practices, restrictions and fund availability (Gumede 2022). Wholesaler and retailers are influential in that they control the final market access of agricultural products (availability and marketing), and directly affect the final pricing and quality (Vink and Kirsten 2002; Greenberg 2017). The export and international traders influence is motivated by their role in the SA agricultural export economy including international demand, export trade balance and product uptake (Potelwa et al. 2016). A few stakeholders have a high interest but moderate influence such as smallholder/emerging farmers, machinery/equipment suppliers and regulatory agencies. When developing a business case and or collaboration venture for CSRA, understanding these influences can provide direction on what institutions or stakeholders to approach to help maximise collaboration efforts and outcomes.

Moreover, stakeholder engagement is often driven by internal and external factors. These can be best understood as inside or outside factors that contribute to an effective environment where cooperation and collaboration can take place. In a multi-stakeholder sector like the agricultural sector, it is important to establish common ground which leads to more effective goal sharing and problem solving. Such an understanding aligns interests and expectations. Looking at Annexure 7, the most prominent internal factors are centred around profitability, market access and competitiveness, sustainability, quality assurance, customer satisfaction, financial support and accessibility, funding for development, innovation and technology, efficiency, collaboration, research and development, capacity building, as well as policy, regulatory and compliance. While some factors overlap, the most prominent external factors are centred around climate change, environmental challenges, sustainability, regulatory pressure, economic pressure, policy dynamics, global competition, market access, market demand, consumer preferences, food security, food health, financial support, as well as collaboration and partnerships. These aids in developing relent collaboration efforts around opportunities identified and that can address existing challenges (see Annexure 7) with CSRA principles where applicable.

10.10 Stakeholder perception, sentiments and concerns about CSRA

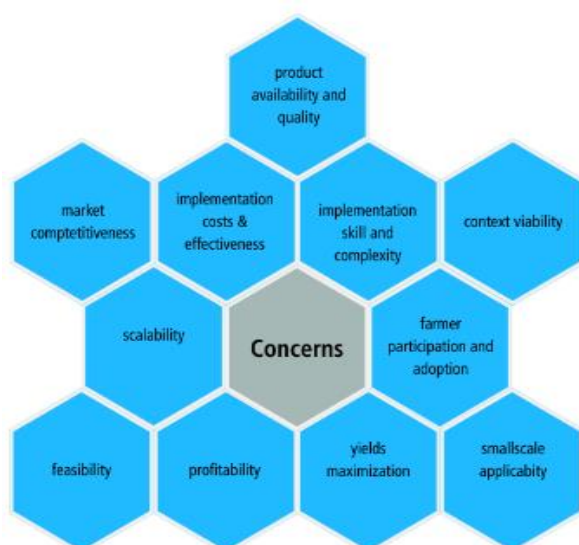
The SA agricultural sector is filled with a variety of stakeholders and institutions as explored above. It is therefore important to acknowledge the similarly varying perceptions and sentiments about farming



systems and practices. There is an undeniable recognition of climate change and its related environmental challenges as well as a growing interest in sustainability that make a strong advocacy for change. It is agreeable across literature that such a change might be only achievable through sustainable agricultural practices that are climate-resilient. Although in differing contexts and at varying levels, climate smart regenerative agriculture (CSRA) is viewed as an important tool for improving soil health, increasing biodiversity, building climate resilience, and achieving long-term sustainable agriculture and food security – by most stakeholders and institutions (see Figure 10.4).

Figure 10.4 Institutional and stakeholder perceptions and sentiments about CSRA

However, some institutional- and stakeholder-specific concerns exist. These concerns are mostly related to some economic and profitability issues, scalability and feasibility, implementation and other complexities, market competitiveness and export concerns, as well as related policy and support



structures (see Figure 10.5). These are key in identifying potential areas of collaboration, intervention, opportunities and alignment. They provide key insights that can benefit the SA-Netherlands collaborations such as leveraging expertise, exposing targeted knowledge sharing, guiding joint research and development initiatives, developing cost-effective solutions, facilitating joint policy advocacy and informed policy decision making, enhancing market access and investments, and building a stronger more impactful relationship (Pannell et al. 2006; Pretty 2008; FAO 2010; Thierfelder et al. 2015; Smith et al. 2017; Kassam et al. 2018; Giller et al. 2021; Beacham et al. 2023; Blignaut et al. 2024; Maluleke et al. 2024; Wilson et al. 2024).

Figure 10.5 Institutional and stakeholder concerns about CSRA

While institutions and stakeholders express mixed sentiments about CSRA, their involvement is steadily increasing in response to escalating climate challenges. The urgent need for solutions that are not only sustainable but also adaptive and resilient is driving broader engagement across all levels, reinforcing CSRA's relevance as a strategic priority in agricultural development and policy planning.

10.11 Network analysis

From Annexure 7 the key players include livestock associations and wool organisations promoting regenerative grazing, improved feed efficiency and animal welfare; agribusinesses and cooperatives supporting sustainable feed, breeding and traceability systems; and research institutions investing in heat stress studies, sustainable soil management, pest-resistant crops, and CSRA training programmes. Companies involved in veterinary health, feed, pest management and input supply are facilitating CSRA by reducing chemical reliance and offering CSRA-aligned solutions. Exporters and processors are also encouraging sustainable sourcing and energy-efficient practices. Various CSRA projects highlight collaboration on low-cost, sustainable technologies and farmer capacity building. Table 10.4 below shows key CSRA activities from Annexure 7 by commodity sector (grains and oil seeds, livestock and horticulture). A review of these CSRA activities show a strong alignment towards core CSRA principles that include conservation agriculture, regenerative grazing, efficient technologies, water and nutrient efficiency, low-carbon processing, and climate-resilient seeds and breeds. Green financing, precision agriculture, traceability and sustainable sourcing also emerged as a common theme. These alignments provide a strong foundation for collaboration through technology transfer, co-investment and financing, farmer education and training, and trade (climate-smart exports).

Table 10.4 *Key CSRA activities*

Commodity & sector	Top CSRA activities	Dutch collaboration/opportunity	Gap
Cross-sectoral	National and provincial CSRA policy alignment	Support climate-smart education and curricula (e.g. WUR, RAUF, Nuffic and others). Use of the Dutch weather/climate decision-support platforms in different SA production regions. Promote green finance programmes targeting CSRA adoption (e.g. FMO: Development bank). Leverage on support to co-fund CSRA pilot zones in SA (e.g. Netherlands Embassy, ROV, LAN).	Limited CSRA-aligned financing instruments, insurance products and incentives. Slow uptake of CSRA due to some farmer bottleneck like education, technologies and capital. Lack of localised research pilots and data accessibility. (Un)availability to effective and efficient CSRA technologies and equitable access them. Integrated water and soil health systems. CSRA-linked certification systems.
	Green & sustainable financing, climate insurance, tax incentives & investment in CSRA projects		
	Climate data tools, weather systems, and decision support		
	Farmer education, CSRA training, and climate advisory support		
	Research collaboration, innovation hubs, and CSA webinars/case studies		
	Public-private partnerships and multi-stakeholder platforms		
	Inclusive value chains and smallholder-focused interventions		
	Carbon tools		
	Effective and efficient CSRA technologies		
Grains and oil seeds	Conservation agriculture (CA): no-till, crop rotation, cover cropping	Share expertise in precision agriculture and soil health monitoring (WUR involvement). Create partnerships for drought-resistant and CSRA-aligned seed provision. Supporting sustainable input supply and farmer training through Dutch agricultural technology firms (e.g. AgriFirms). Support localised pilots for CSRA storage innovations.	Lack of localised climate-adaptive seed varieties. Lack and underutilisation of digital tools. Insufficient (but growing) data on CSRA adoption success stories. Strong monitoring and evaluation of soil health outcomes and benefits from CSRA adoption. Existing farmer adoption bottlenecks like finance, scalability, and training.
	Precision agriculture and water-efficient irrigation & conservation		
	Reduced chemical use, organic practices		
	Soil health and fertility management		
	Climate-resilient seed development		
	Smallholder support & CSA farmer training		
	CSRA data assessment tools		
	Grain traceability & sustainable sourcing		
	Eco-storage		
Cattle (beef & dairy)	Rotational & regenerative grazing	Collaboration in low-emission beef value chains with the Dutch meat industry. Partnerships for sustainable beef feed. Joint research and development on carbon footprint tools and greenhouse gas calculators. Extended CSRA-aligned dairy programs and low-carbon processing tech. Co-develop regenerative grazing and feed optimization tools. Leverage on Dutch NGO partnerships for CSRA smallholder farmers' support. Joint Dutch-SA research.	Gaps in feed innovation, logistics and cost-effective alternatives. Limited carbon measurement & certification. Limited consumer education and market alignment for climate-smart products. Expanding CSRA-specific financing mechanisms. Market-based incentives for CSRA adoption. Climate-resilient infrastructure. Developing consistent CSRA policy support and alignment across
	Feed sustainability and land-use optimisation or pasture management		
	CSRA feed systems		
	Animal health and disease resilience		
	Climate-smart beef certification & traceability		
	Farmer training and local advisory support systems		
	Sustainable milk processing, low-carbon dairy products		

	Renewable energy and energy-efficient processing systems	Provide market and export certification from Dutch value chain agencies.	sector. Digital agriculture tools for precision farming.
Sheep & goats	Regenerative grazing, erosion & overgrazing control		
	Climate-resilient breeds		
	Low-input farming systems		
	CSRA traceability		
	Farmer support & education		
Pigs	CRSA-aligned feeds		
	Energy-efficient housing and waste systems		
	Carbon-smart feed-to-pig conversion systems		
	Carbon footprint reduction		
	Improved animal health		
Poultry	Integrated poultry-crop systems		
	Sustainable and efficient poultry feed		
	Energy-efficient housing & technologies		
	Water conservation & waste management		
	Environmentally sustainable poultry processing and sourcing		
	Climate-resilient management		
Horticulture	Poultry health & reduced antibiotic use		
	Organic and regenerative farming	Co-develop water-efficient systems. Partnerships for CSRA traceability and EU compliance. Leverage on models to support smallholders' horticulture.	Access to CSRA technology. High adoption costs for emerging producers. Inconsistent CSRA compliance and sustainability in cold chains. High chemical dependency.
	Integrated pest management (IPM)		
	Efficient irrigation & water conservation		
	Soil health		
	Eco-friendly packaging & cold chain efficiency		
	CSRA traceability & export compliance		
	Certification		
	Support for smallholder farmers		
Processing	Energy-efficient processing	Collaboration in agri-processing and cold chain solutions. Co-developing and financing joint innovation hubs. Logistics optimisation tools.	High energy use and low decarbonisation in processing hubs. Sustainable sourcing policy gaps. CSRA reporting and transparency.
	Climate-smart waste management		
	CSRA-aligned sourcing, traceability, and certification		

While several South African institutions and value chain actors present some level of collaboration, opportunities for collaboration with the Dutch partners, particularly in areas aligned with Dutch strengths in sustainable agriculture, agri-tech and water management exist. For example, research entities working on CSRA offer potential for joint research, innovation hubs and capacity building exchanges. Other opportunities include those in sector organisations engaged in regenerative grazing, feed efficiency and traceability align well with Dutch expertise in precision livestock farming, animal health and low-emission technologies. Similarly, companies and cooperatives implementing efficient irrigation, water harvesting and sustainable soil management could benefit from Dutch innovations in smart irrigation systems, digital water risk mapping and agro-ecological zoning. The Netherlands can also contribute to expanding CSRA-linked certification schemes, market access strategies and climate-smart financing models, areas where Dutch agri-business and institutions have robust experience.

The stakeholders advancing CSRA in South Africa demonstrate a growing convergence between environmental responsibility, technological innovation and market-driven sustainability. The climate smart activities that they are involved in need to be supported by efforts in capacity building, climate-resilient research, sustainable financing and technology adoption. Strengthening collaboration between public institutions, private actors and local farming communities will be critical to closing these gaps and realising the full potential of CSRA in building a resilient and inclusive agricultural future.



Part E

DISCUSSION AND CONCLUSION

Chapter 11 Advancing climate smart regenerative agriculture: challenges and opportunities

11.1 Introduction

To advance climate smart regenerative agriculture (CSRA) in South Africa, several challenges must be overcome and the opportunities that exist must be developed. Based on the information contained in Chapters 0–10, the challenges and opportunities can be categorised, irrespective of the branch of agriculture, into four interrelated themes. These themes are as follows:

1. Finances, funding mechanisms and access to resources
2. Training, awareness, capacity and research
3. Trade and value chain related matters
4. Technology

These themes will subsequently be discussed with reference to an overview of the general challenges that are present with a subsequent focus on a selection of specific opportunities that can be actioned within the short- to medium-term. The shortlist of opportunities is by no means an effort to be comprehensive but has been selected based on the possibility of being executed within a relatively short space of time with direct benefits in the short-term.

11.2 Finances, funding and access to resources

11.2.1 General challenges

Often both the access to and the availability of finances to assist a producer to adopt and convert to CSRA are limited because producers seek to adopt CSRA when they experience some financial trouble. CSRA is therefore viewed as a rescue mechanism, a parachute, following years of applying conventional agricultural practices. The motivation for adopting CSRA is thus turned towards financial survival when conventional practices have failed, and/or the resource, that is the farm, has become degraded. Such a degraded resource has, per definition, a reduced potential. Being in debt with a resource with a low and declining potential hampers both the ability to attract finance and the ability to adopt and implement CSRA.

A more prudent approach would be to adapt farming practices before experiencing financial difficulty. This will have financial, social and environmental benefits as noted within the preceding chapters. There are, however, challenges that prevent the producer to convert to CSRA before running into financial difficulties. A general list of these challenges is discussed below under three sub-headings.

Category 1: A mismatch between private costs and public benefits

CSRA farmers are currently expected to pay for the transition to and the roll-out of CSRA at own cost and risk. Such a transition does involve multiple public benefits which are currently unpaid for by the participants in the value chain, be it the input suppliers, financiers, wholesale and/or retail outlets. These benefits, as mentioned and highlighted in earlier chapters, include:

- improved system resilience and hence food security;

- improved food and soil quality;
- improved water, carbon and other nutrient flows;
- improved biodiversity; and
- benefits to a range of ecosystem services such as climate amelioration, water provisioning and regulation, soil erosion prevention and a sense of place.

Currently farmers sell a single ecosystem service, namely the commodity at hand be it maize, wheat, fruit, meat and/or vegetables. Viewed from an ecosystem service perspective these commodities are categorised as provisioning ecosystem services. Rural landscapes and farms, however, contribute to much more than provisioning services only and it includes regulating, cultural and supporting ecosystem services. These services comprise benefits such as climate amelioration, water provisioning and regulation, soil erosion prevention and a sense of place, to mention but a few. These services constitute societal (public) benefits. This is since the benefits befall society at large and all the participants in the value chain. They do accrue at the expense of the private investment by the farmer though. This emphasises the mismatch between the public benefits and the private costs. Converting to CSRA has a range of public benefits, and it is in the public interest for farmers to do so also from a food security and system resilience perspective, but currently these benefits are on the back of the farmers' private expense. While this mismatch prevails, the public demand for the services will be higher than the private offering. The private offering is curtailed due to financial resource constraints and the fact that there is no adequate compensation for the non-commodity linked ecosystem services a farmer is producing.

Category 2: A mismatch between short-term needs and long-term benefits

Most of the benefits of CSRA, such as improved soil health, climate resilience and nutrient dense food, will be realised only over the medium- to long-term. Like with any other intervention, unlocking these benefits requires investments at the outset of the transitioning from a conventional way of farming to CSRA. These investments could be substantial. This temporal phenomenon is often referred to as the investment J-curve whereby an upfront financial investment is required in anticipation of longer-term gains. Once again, this is not unique to the transitioning to CSRA – the investment J-curve is relevant in all investment or capital allocation decisions. What is required is appropriate funding models that provide patient capital to support producers to transition to CSRA.

The temporal misalignment is exacerbated by further a misalignment between the traditional financing models and the specific needs of CSRA which, for example, requires an increase in livestock for re-incorporation into cropping systems and to graze natural grasslands. There is also a lack in fully adapted risk-assessment models that embrace the long-term benefits and resilience of CSRA. This translates to farmers and agri-entrepreneurs facing high and increasing uncertainty when applying for loans or attracting investments. In addition, there are inadequate insurance instruments serving CSRA, specifically to support the long-term nature of the journey to transition from a conventional to a CSRA system.

Category 3: A mismatch between bio-physical and research needs and financial demands

A farm is a dynamic, agri-ecological system operating in a unique climate-ecological area. Biological processes are not linear. Farms are not factories and maize fields are not uniform production lines. Current financial models supporting primary agriculture, however, presupposes precision. The financial demands are thus placing enormous stress on farmers who are operating in a complex and dynamic biophysical context.

Lastly, there is also a lack of financial information and research pertaining the economic costs and benefits of different CSRA practices in all branches of agriculture, but especially within horticulture, both internationally and locally. The impact that these practices have on farming output has not yet

fully been quantified (yields, fruit quality and related prices, water consumption changes, etc.) and therefore changes to farming incomes cannot be accurately measured. And therefore, cannot yet feed into financing models.

11.2.2 Shortlist of specific opportunities

Development of a finance programme that targets CSRA adoption, products and services

To accelerate the uptake of CSRA and to provide access to the desired technologies, an opportunity exists to develop a two-tiered finance and investment programme that focuses on the farmer and on agri-businesses. These will be discussed separately.

CSRA finance and investment accelerator for producers

To bridge the mismatches highlighted above an innovative finance and investment programme is required whereby investors and development agencies can invest in production enterprises. Thereby they can internalise the public benefits CSRA is rendering while contributing to the cost of the investment and assist the farmer in the transitioning through the CSRA J-curve. Thereby the investors will contribute towards healing the land and the food system, and thus produce improved quality food and built system resilience.

This can be done in collaboration with, for example, a local blended finance vehicle called Restore Africa (<https://www.restore-africa.com/>). By investing in Restore Africa an equity investor invests in CSRA practices while sharing in the upside thereof over time. The equity contribution is further appropriately and conservatively blended with debt finance to reduce the overall cost of capital. It is very important to balance the (more) patient but more expensive equity capital, with patient but comparatively cheaper debt finance when considering income tax deductibility of interest. Matching capital sources with underlying the nature of capital requirements (longer term productive capacity base funding versus shorter term input and running expenditure funding) supports cash flow and capital structure optimisation.

The Restore Africa model is based on a co-shareholder arrangement between the producer (land custodian) and the investor who both acquire an equity share in the production enterprise – and is described in Blignaut (2019)¹⁸. The equity finance is used to co-fund the transition and is thus, by definition, linked to a longer timeframe than that of a commercial production loan. An equity investor does carry part of the risk of the farming enterprise, but also share in the long-term financial returns. The equity partner also shares in the environmental return of a land that is being healed and all its associated public benefits such as carbon sequestration, improved water flow and regulation, enhanced nutrient flow, etc. These benefits could be quantified and be linked to the investments made. As mentioned above, the equity funding is further appropriately blended with debt funding.

The role of development finance institutions (“DFI”) is very important in this space. DFIs often serve the role of funder of last resort. Their unique positioning, role and responsibility provide the platform to catalyse change – both in catalysing and crowding in other funders’ capital as well as catalysing on-farm change. Dutch DFIs and other private companies could invest in CSRA in South Africa using this operational mechanism.

¹⁸ Blignaut, J.N. 2019. Making investment in natural capital count. *Ecosystem Services*, 37:100927. <https://doi.org/10.1016/j.ecoser.2019.100927>.

CSRA finance and investment accelerator for agri-businesses

The same instrument mentioned above with respect to producers can be used to support both existing as well as new agri-businesses that develop and promote technologies and products aimed at CSRA. This will act as a strong stimulus for the growing agri-business ecosystem that desires to support CSRA in South Africa, but which require the necessary support to scale.

Investments could take the form of joint agri-tech innovation hubs, and funding for agri-tech start-up companies aimed to support CSRA.

The more industry support there is for CSRA with long-term equity investors that seek both a financial and an environmental return, the more farmers will be able to adopt CSRA practises.

11.3 Training, awareness, capacity and research

11.3.1 General challenges

As noted in Chapter 0, CSRA is a farming system which enhances the natural ecosystem and specifically soil health and system resilience. The multiple benefits derived from this has been highlighted and illustrated through numerous case studies. These benefits further enhance the delivery of all major ecosystem services. One of the outcomes thereof is that the input cost to produce food are often reduced over time. Reduced input costs do not support the agri-businesses that benefit from selling those inputs in the short-term – agri-businesses whose profits depend on selling those inputs and which therefore profits from conventional agriculture. They tend not to support and invest in training, awareness outreach programmes, capacity-building and research which enhance system health and that will diminish their profitability. There is therefore a strong triangular relationship between:

- financial institutions issuing short term production loans,
- agri-businesses promoting their core business, and
- the research and training offering from leading tertiary institutions that supports conventional agriculture due to the industry support thereof.

This triangular relationship limits the investment in training, awareness raising, capacity and research leading to three notable challenges linked to the size of the operation, the level of training material being available, and the scope of such material. These will subsequently be discussed.

Category 1: Scale or size of the operation

The lack of funding and investment in CSRA training, awareness and outreach programmes, extension services, capacity-building and research has several undesirable impacts linked to the underinvestment therein. The underinvestment has led, among others, to a lack in appropriate knowledge pertaining to CSRA systems and applications across all scales of operations and across the various branches of agriculture. That is since the research and training needs for, for example, the livestock sector is different than that for grain crops and horticulture. The needs are also different among small-scale subsistence farmers, small commercial, and large-scale commercial operations. Smallholder and communal farmers, for example, lack access to updated training, technical advice and localised extension services which hinders the adoption, limits farmers' abilities to understand, measure and benefit from the environmental and economic benefits associated with CSRA.

Category 2: Academic level and type of training

The limited support and investment in CSRA are mirrored by an inadequate incorporation thereof in the curricula of training and capacity programmes at all levels of training, be that secondary schools, tertiary level, agricultural colleges. Training in CSRA is either considered a lone-standing module, or not considered at all.

In most places of learning the different aspects of CSRA, such as grazing and veld management, genetics, animal health, finances, ecosystem restoration, are taught in different departments, and often are not part of an integrated course or module leading to silo-thinking and operation. This hinders real-world application.

The limited investment in CSRA has also led to a reduction in the research plot sizes and the scale and location of the research and training facilities. Farms are large-scale operations, and the reality is that plot-size and on-station (vs field-size and on-farm) training and research has a limited reach and impact and cannot simulate on-farm realities.

Many schools in South Africa have included agricultural subjects or are predominantly agricultural schools, but they need further support, guidance and finance in the development and/or execution of appropriate CSRA curricula.

Category 3: Scope of research

There is a lack of appropriate CSRA systems research including all the elements, such as the economic costs and benefits of different CSRA practices across all branches of agriculture, but notably within horticulture. The impact these practices have on yields, fruit quality, prices, water consumption, profit has not yet been quantified and therefore changes in farming revenue have not been accurately measured. Given this lack of information, there is insufficient information to support financing models for CSRA.

There is also a serious lack of research pertaining to the execution of CSRA in various contexts, such as high-density grazing and animal integration. Involving key stakeholders, especially farmers in the research process, is often neglected by research institutions and initiatives, which is leading to a poor impact.

11.3.2 Shortlist of specific opportunities

Development of a joint research and training curricula and awareness programme promoting CSRA

To accelerate the development of information and skills and the availability thereof to the producers a joint Dutch-South Africa research and training and awareness programme is proposed that would offer opportunities for public and private sector alike as well as for DFIs. This could be done by focusing both on on-farm requirements as well as that pertaining to the industry at large.

On-farm CSRA training, research, and awareness programme

To overcome the lack of on-farm knowledge, financial information, extension services, etc., a joint research, training and awareness programme between South African and Dutch public and private institutions of learning, such as NGOs, will be mutually beneficial and offer bilateral opportunities for

learning. Some NGOs are already active in this space, such as ASSET Research (<https://assetresearch.org.za>) and Mahlathini Development Foundation (<https://mahlathini.org/>) forming part of a wider network of local practitioners who could be approached for collaboration.

There are several research and training gaps within the different branches of agriculture. Livestock, for example, requires a careful balance between grazing management within fragile ecosystems, profit and herd management as well as animal welfare and health aspects inclusive of, among others, genetics. There are both public and private benefits, and thus require both sectors' involvement. While the public sector is responsible for training, the private sector has a big role to play within developing genetics. There is also an acute lack of research on the economic costs and benefits of different CSRA practices within horticulture, both internationally and locally. The impact that these practices have on farming output has not yet been quantified (yields, fruit quality and related prices, water consumption changes, etc.) and therefore changes to farming incomes cannot be accurately measured. This information is thus not available to feed into financial models. This, also, has both public and private sector implications. While the research and training and knowledge generation is a public sector activity, the development and the application of the information is within the domain of the private sector.

Arguably the best form of encouraging the adoption of CSRA is through farmer-to-farmer exchange initiatives to share best practices in CSRA. This would include bilateral exchange programmes between Dutch and South African farmers to explore different modes of operation and the application of different technologies within different context. Agri-businesses that seek to promote CSRA has a major role to play in encouraging such exchange programmes.

The joint training, research and awareness programme could further involve institutions such as DALRRD, AgriSETA, NAMC, ARC, RVO, LNV and FMO, but be focused on the development of an encompassing CSRA curricula at all levels of learning, and for all the branches and scales, or sizes, of production. This would involve accredited CSRA curriculum development, e-learning platforms and apps, field-based demonstration hubs, long-term extension support, farmer-to-farmer mentorship programmes and could be as far-reaching as information packages at school-level to joint PhD programmes. These could be paid for, at least in part, through the CSRA finance accelerator mentioned above, and by the industry itself.

An existing CSRA school initiative in the eastern Free State Province of South Africa, the Reitz Agricultural Academy (<https://www.reitzlandbouakademie.co.za/index.php/en/>), has just completed accredited training curriculums for conservation and precision agriculture on NQF level 6. This initiative could be further supported and scaled out to other schools through scholarships, and various other practical, infrastructure and knowledge-exchange collaborative projects.

CSRA industry training, research and awareness programme

While the on-farm training, research and awareness programme addresses the farmers' needs, this opportunity is within the ambit of the supporting value chain and agri-businesses. While there are various role-players in the value chain that supports CSRA activities, one key element thereof is that of laboratories involved in aspects such as soil analysis and water testing. As the saying goes: to measure is to know. A producer will only know if the on-farm soil and water quality is improving if it is adequately and regularly measured. That requires readily available soil and water testing instruments

and labs that can do the analysis. In addition, there are the benefits that could potentially be derived from remote sensing. For example, converting remote sensing data such as NDVI (Normalised Difference Vegetation Index) to on-farm biomass production has eluded producers and the industry alike till today and it will be highly beneficial if such a system could be developed.

One of the biggest challenges within especially intensive agricultural systems such as dairy and fruit production and processing is wastewater generation. Bioremediation is an environmentally friendly and CSRA compliant way of water treatment. While there are enterprises in South Africa focusing on such, they would require support and external investment in order to scale-up.

The development and implementation of country-wide information platforms and farmer-friendly tools for grazing, irrigation, planting, etc. such as FruitLook (<https://fruitlook.co.za/>), DESTiny (<https://assetresearch.org.za/destiny-tool/>), and a bespoke version for livestock management inclusive of stocking rates, genetics and finance should be developed and be made available with the information shared between the countries to enhance CSRA, the adoption and promotion thereof. The information contained therein could also be used to assist in product labelling and certification which would lead to improved market access.

11.4 Trade and value chain related matters

11.4.1 General challenges

Within the South African context, food produced in a CSRA-compliant manner is not differentiated from food produced in a conventional agricultural system. The infrastructure and traceability network do not support a dual food production system. For example, where a cash-crop has been planted on a field that had cover-crops and which were grazed by animals and which was planted in a no-till method with minimal chemical intervention, is offloaded into the same silo as a conventional produced cash-crop. There is therefore no differentiation at market level.

Similarly, fruit that is exported has a certification body to certify the production system, but very few farms are either certified organically or have bio-certification as in Europe. The cost of the certification is normally charged either Euros or USD and it does not warrant the certification as the certification does not yield a sufficient price margin. Also, too often the certification is driven by an ideology and does not have any contextual reference to the farmers management system, or any contextual reference to the farm's environment.

Another problem within the Southern African context is the distance the producer is from the market. The farmers' direct regional market is too small to compensate them for their produce. The management of the fresh fruit and vegetables, or animal products by the chain stores, is received centrally, and then distributed to chain stores. This often results in the produce traveling double the distance. During this distribution process produce from a farm that applies CSRA is mixed with those produced conventionally.

Given this introduction, the challenges pertaining to trade and the value chain, can also be summarised in three categories, namely certification and regulation, value chain and beneficiation.

Category 1: Certification and regulation

Existing certification processes are very cumbersome and expensive and have yet to fully integrate CSRA production as a competitive advantage. Without efforts to harmonise sustainability standards and market signals (differentiated branding/export incentives for CSRA products), CSRA risks being side-lined in international trade (especially when competing with more streamlined sustainability frameworks).

Growing international demand for sustainably produced animal products, could open premium markets if South African producers can meet stringent environmental standards, but there is a gap in the translation of these sustainability credentials into tangible export advantages. This is further hampered by complex regulations, particularly in food safety standards, create challenges for South African exporters.

Furthermore, there is a serious lack of technology and systems to enhance product traceability, and that limits trade options since importers are increasingly sensitive to the origins of the products they buy. In addition, product labelling, notably the process followed by the EU-PEF (product environmental footprint), is biased against naturally produced products and fibres, such as wool.

Category 2: Value chain channels

South Africa imports a significant amount of technology and machinery but has not established strong channels for CSRA technology transfer or joint ventures, limiting local capacity building. This is hampered by substantial logistical challenges which include distance and transportation costs that affect competitiveness. This is further hampered by port issues which result in delays and transporting additional distances to overcome delays affected the quality of notably the horticulture industry and added additional costs to producers.

The export market is also highly susceptible to economic fluctuations such as the currency volatility that can impact trade. While currency hedging is available, the knowledge thereof and access to such is limited. The problem is exacerbated by a lack in insight into consumer preferences abroad.

Within the livestock sector the challenges are magnified because of the stringent EU sanitary regulations.

Category 3: Beneficiation

Because of unfavourable tariff barriers for beneficiated products in especially the EU, most agricultural exports are raw products rather than processed goods. This is since raw products or commodities are exported without having to face high tariff barriers. Beneficiated products, however, do have high tariff barriers. One such example is that of coffee. Green beans are exported with no tariff, but roasted beans have a high tariff. This acts as a barrier to local beneficiation and the development of the sector.

11.4.2 Shortlist of specific opportunities

Development of a mutually beneficial CSRA trade and exchange programme

To foster mutually beneficial trade and exchange requires, as a minimum, a system which will allow product differentiation (both locally and abroad), and the development of technologies and bio-products within the value chain.

Product differentiation

Be it grain crops, livestock or horticulture and be it domestic trade or bilateral trade with the Netherlands, if the CSRA-compliant commodities cannot be differentiated from those produced conventionally, then the market development of CSRA will remain constrained. For example, currently there are very stringent export requirements for beef pertaining to biosafety and feed supplementation. Those requirements are mainly relevant to beef raised in feedlots. Grassfed beef production are, for the most part, hedged against the biosafety issues feedlots are facing yet they can also not be exported because of a lack in product differentiation, both locally and abroad. Likewise, wool that is produced in an environmentally benign manner using CSRA principles and that produced in an extensive large-camp selective grazing context are classified uniformly based on the wool grade. Fruit has to comply with EU-standards and standards such as GLOBALG.A.P. which is largely focused on aesthetics rather than fruit health or the healthiness of the production method.

The development of suitable and recognised ways of differentiating between commodities will expand the market access to CSRA. This will require the development of technology and systems to enhance product traceability from farm-gate to shop floor with an appropriate and affordable system of differentiating among the various produce. This would require, among others, the development of a digital information guide as to products and commodities combined with a trade platform that could enhance the development of new markets, especially for artisanal and niche products, and facilitate trade. For example, if a product is produced in a CSRA-compliant manner in either South Africa or the Netherlands, it could be uploaded and registered onto the digital platform with a barcode and be marketed within a separate value chain.

Such product differentiation could also be promoted among small growers by assisting them to form co-operatives and sell their produce in bulk through the aforementioned digital platform.

Value chain development

South Africa imports a significant amount of technology and machinery but has not established strong channels for CSRA-related technology transfer. These would include, but is not limited to, the latest crop protection and soil health technology that is available in the Netherlands that will support CSRA system development. This would also include the access to and availability of bioproducts.

Advanced products such as bio-fertilisers and plant bio-stimulants and technologies exist in both countries that need proper investigation and discussion as to their benefit and relevance in both countries. This is since much research and development (R&D) has been ongoing on this with the development of products covering, for example, waste management using enzymes to break the waste and particulates down. It is important to have a good understanding what products and technologies are available in both countries to enable trade and the development of these while promoting CSRA. These bio-products would further include products that would enhance soil health and the precision application thereof.

South Africa furthermore produces a large quantity of raw agricultural products that would benefit greatly from processing and value addition. Dutch companies, with their expertise in agro-processing, could invest in South African industries to add value to their products and increase competitiveness. This could involve introducing sustainable packaging solutions and investing in food processing plants. This would strengthen existing markets where Netherlands is a main recipient such as table grapes, wine, citrus, blueberries, avocados and rooibos tea while supporting small growers in rooibos and fynbos sectors. It could also include investments made in local processing facilities to export value-added products like fruit juices, canned goods and specialty foods.

11.5 Technology

11.5.1 General challenges

CSRA is an art rather than an exact science – it requires the careful balancing of the interaction of several living systems within a dynamic and complex site and regional specific context. All the on-farm resource aspects must be managed to produce nutrient dense food and improve biodiversity while the farmer must stay financially able to do this. Within this unsure context the farmer must choose the most appropriate technologies to assist and inform decision-making. Unfortunately, there is significant knowledge and implementation gaps between which affordable tools and technologies are available and what farmers know is available and have the capacity to use. Farmers must therefore both know what is available and be able to use it on the farm within the local context – and be able to afford it.

The uptake of state-of-the-art technologies are, for the most part, limited because they are expensive. The problem is magnified when considering small-scale and logistically challenged resource-constrained producers.

11.5.2 Shortlist of specific opportunities

Development of bespoke CSRA technologies

Both the producers and service providers need to consider existing technologies that must be repurposed within a CSRA context and seek to develop new technologies where there are gaps between needs and means. The technologies involved will involve both software and hardware.

Software options

As mentioned above there are information and knowledge gaps pertaining to on-farm financial and production information as well as product differentiation. There is therefore a need to develop a system that would assist producers with the tracking of their costs and purchases as well as the marketing of their produce without burdening them with an additional administrative load.

This would imply the development of a one-stop system that would allow a producer to upload purchases, do the financials, track profitability, monitor soil health, grazing availability and water quality, or whichever is relevant, and upload the product credentials for marketing. The product is then labelled, differentiated and marketed as such. Once the product be sold the sales price and client would be added.

Such a system will have multiple uses including financial monitoring, research as well as marketing and product differentiation.

Hardware options

Technological improvements that focus on freeing the producers' time so that they can concentrate on producing food within their contexts that is nutrient dense, boosts or enhances biological systems,

and reduces their input costs. This can include in-field and mobile robotic milking machines, and systems to improve feed mixing. The development of bespoke technologies through either technology partnerships or joint ventures in developing climate-smart agricultural technologies can benefit both nations and can include, but is not limited to:

- Renewable energy such as which is listed in GreenCape's Sustainable Agriculture Market intelligence reports, that includes biogas for the fruit processing, dairy and feedlot sectors.
- Renewable energy that is cost-effective, durable and applicable for farms and remote areas.
- Mobile dairies and in-field abattoirs to reduce the stress on the animals as well as enhanced biosecurity while not compromising CSRA principles.
- Greenhouse technologies which are linked to precision farming and includes vertical farming.
- Various field-scale CSRA green or electric vehicle (EV) equipment on different scales, e.g. tractors, no till planters, etc.
- Improved water efficiency technology such as probes and irrigation tools.
- Hand-held and/or in-field soil and crop quality monitoring, measuring and data collection/capturing instruments and systems, e.g. soil fertility and biology and nutrient density.

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Association	Website
ARC-Tropical and Subtropical Crops (ITSC)	https://www.arc.agric.za/arc-itsc/Pages/ARC-ITSC-Homepage.aspx
BerriesZA	https://www.berriesza.co.za/
Cape Flora	https://www.capeflorasa.co.za/
Citrus Growers Association of South Africa	https://www.cga.co.za/
Citrus Research International	https://www.citrusres.com/
Fresh Produce Exporter's Forum SA	https://www.fpef.co.za/
Fruitlook	https://fruitlook.co.za/
Fruit SA	https://fruitsa.co.za/
HortGro	https://www.hortgro.co.za/
Macadamias South Africa NPC (SAMAC)	https://samac.org.za/
My Sherpa	https://www.mysherpa.co.za/
NAMC	https://www.namc.co.za/
Potatoes South Africa	https://www.potatoes.co.za/
SA Wine Industry Information and Systems	https://www.sawis.co.za/
SAMGA South African Mango Growers Association	https://mango.co.za/
Seedling Growers' Association of South Africa (SGASA)	https://southafrica.co.za/seedling-growers-association-of-south-africa.html
South Africa Wine	https://sawine.co.za/
South African Avocado Growers' Association (SAAGA)	https://avocado.co.za/

South African Litchi Growers' Association NPC (SALGA)	https://litchisa.co.za/
South African Union of Marketing	http://www.saufm.co.za/
South African Pecan Nut Producers Association NPC (SAPPA)	https://www.sappa.za.org/
South African Rooibos Council (SARC)	https://sarooibos.co.za/about-the-council/
South African Sub-Tropical Fruit Growers Association (Subtrop)	https://www.subtrop.co.za/
The South African Table Grape Industry (SATI)	https://www.satgi.co.za/
VinPro	https://vinpro.co.za/
Wines of South Africa (WOSA)	https://www.wosa.co.za/home/

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ANNEXURE 1: A DESCRIPTION OF DIFFERENT SUSTAINABLE AND RESILIENT AGRICULTURAL CONCEPTS AND SYSTEMS

When discussing CSRA, the principles and practices discussed in Chapter 0 are the most well-known and most widely used. What follows is a brief overview of different agricultural systems or approaches – all of which can also be defined as climate smart and regenerative, have some or all the same benefits and use the principles discussed earlier.

Regenerative agriculture (RA)

Regenerative agriculture goes back to working with rather than against natural systems; grazing animals in ways that mimic plains game on grasslands, using old methods of crop farming, from before the time of chemicals, when the sun was the only source of energy, monoculture did not exist and the carbon and water cycles were still intact. But regenerative agriculture is not backward or backward looking, in fact soil microbiology is the latest, cutting edge science in agriculture. Regenerative agriculture is about farm management that works with nature rather than against nature, forming carbon loops rather than a series of carbon emissions that take carbon from the soil into the sky. This rebuilds the soil, stimulating the microbiology and fixing the water cycle. All of which maximises the photosynthetic potential of that soil capturing more carbon and cooling the planet. Agriculture has the greatest potential for cooling the planet as photosynthesis both draws down carbon and is nature's air-conditioner cooling the environment via transpiration.

(Source: <https://www.regenagisa.org.za/>)

Regenerative

Definition
Regenerative agriculture encompasses numerous definitions.

Schreefel et al (2020) define it as "an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting ecosystem services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production" (Shrestha and Horwitz, 2024)

Principles

- Reduce tillage
- Never leave bare soil
- Maximise plant diversity and productivity on farm
- Integrate livestock and cropping systems
- Reduce or eliminate synthetic agrichemicals
- Dependent upon one another withing a system for them to be optimally successful. (Kabenomuhangi, 2024)

Goals

- Improve soil health, including, the capture of carbon (C) to mitigate climate change
- Promote biodiversity while producing nutritious food profitably (Giller et al, 2021)

References Giller, K. E., Huijbeek, R., Andersson, J.A., & Sumberg, J. 2021. Regenerative Agriculture: An agronomic perspective. Outlook on Agriculture, 50(1), 13-25. Kabenomuhangi, R., 2024. Regenerative Agriculture and Soil Health: Enhancing Biodiversity through Sustainable Farming Practices. International Journal of Research Publication and Reviews, 5(9), 3203-3215 Shrestha, A and Horwitz, D., Variations and Commonalities of Farming Systems Based on Ecological Principles. Crops 2024, 4, 288–307

Climate smart agriculture (CSA)

International recognition for climate smart regenerative agriculture (CSRA) is fast gaining traction given the growing concern that 40% more food will be needed by 2050, while utilising less land, experiencing lower yields and emitting fewer greenhouse emissions. According to the FAO, to meet food demand in 2050, yearly global crop and livestock production would need to be 60% greater than it was in 2006 (Muhie 2022).

Given the additional threat of climate change on the agricultural landscape and the threat of global food and nutrition security, climate smart agriculture was first developed between 2009 and 2013, with the intention of addressing the threats to food production posed by climate change (Robinson

2024). It is defined as “a set of outcomes that concurrently address climate change and development goals” by focusing on:

- improving the adaptive capacity and resilience of farming systems to climate change;
- mitigating the emission of GHGs from agricultural activities; and
- improving agricultural productivity and food security sustainably.

CSA practices are context-specific, considering local socio-economic, environmental and climate change factors.

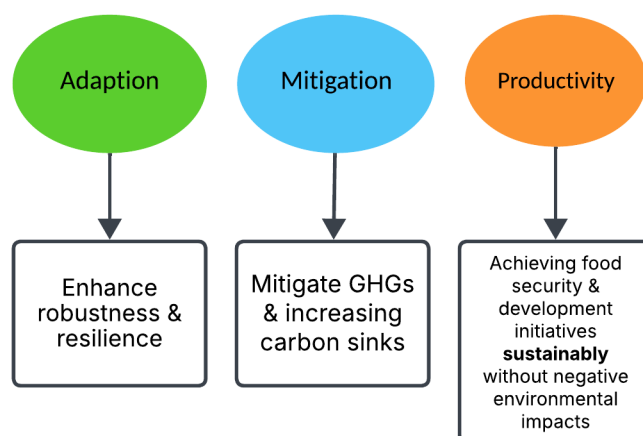


Figure A1.1 Key principles of climate smart agriculture

Source: Robinson (2024)

It aims to give farmers ability to reduce exposure to short-term erratic weather patterns and the tools to adapt and build resilience in the face of longer-term climate changes. It aims at preserving the environment that farmers and others benefit from (Robinson 2024). CSA’s mitigation goal is to reduce or eliminate GHG emissions from food, fibre and fuel. It manages soils and plants in ways that allow them to act as carbon sinks, absorbing carbon dioxide from the atmosphere (Muhie 2022). The productivity aims of CSA address maximising resource allocation and improving techniques to boost productivity and earning. It also stresses food security and the maintenance of rural livelihoods (Robinson 2024).

Agroecology

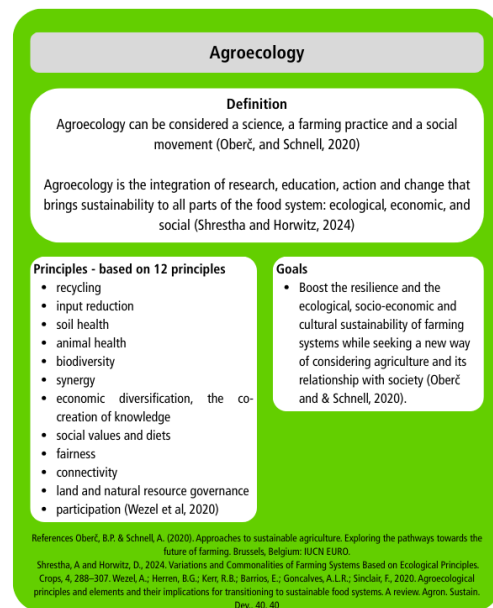
Agroecology – ‘the application of ecological concepts and principles to the design and management of sustainable agro-ecosystems’ – has three facets. These are:

1. a scientific discipline involving the holistic study of agro-ecosystems, including human and environmental elements
2. a set of principles and practices to enhance the resilience and ecological, socio-economic and cultural sustainability of farming systems, and
3. a movement seeking a new way of considering agriculture and its relationships with society.

Agroecological farming is based on homeostasis, self-regulation and biodiversity. As such, it differs substantially from the paradigm of industrial agricultural production: artificial control of natural processes, extensive use of synthetic inputs and genetic uniformity. Agroecology shows greater resilience and environmental sustainability because of its complexity, diversity and adaptive capacity and because it does not deplete the natural resource base. Other important environmental features include the recycling and replenishing of inputs, the emphasis on multi-functional agriculture and the capability to mitigate climate change – as opposed to waste and depletion of natural resources, profit-only oriented models, pollution and greenhouse gas (GHG) emissions.

The focus of agroecology is to integrate as many of the systems present into one and, hence, forms part of an overarching concept. Both ecological and social concepts are taken into account when agricultural systems are designed so that the result is a well-optimised system that benefits both society (in terms of yield and other socio-economic aspects) and the environment – meaning that the yields produced are done so sustainably without lasting negative impacts on the environment (FAO 2018). In 2019, the FAO approved its ‘10 elements of agroecology’, a principles-based document promoting the central role of AE in a sustainable agri-food system (Barrios et al. 2020). The resistance of agroecology against influence or input from prominent Global North agri-food system actors and its perceived rejection of larger-scale producers and food processors may have left an opening for the rise of RA.

However, this comprehensive definition is not widely accepted. Some practitioners prefer a more restricted definition because of the particular evolution of the concept in their country or in their specific field of expertise. Others question the assumptions and the methodological implications of an overly broad approach, given that we lack commonly agreed operational tools and analysis models that can combine the many dimensions covered by such a multidisciplinary approach.

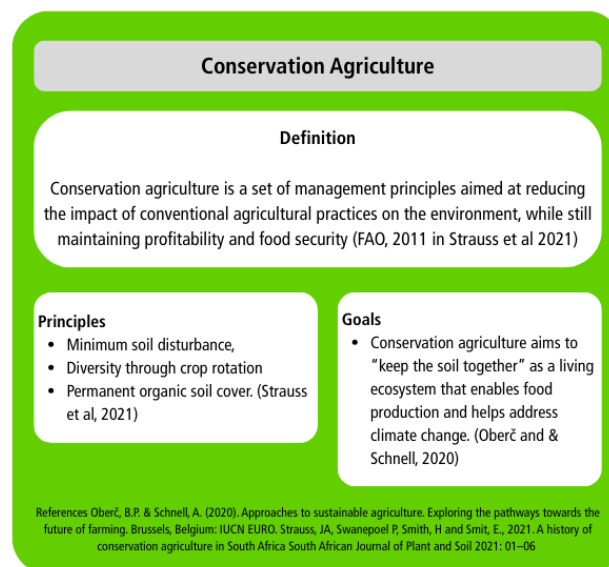


Conservation agriculture (CA)

Conservation agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is characterised by three linked principles, namely:

1. continuous minimum mechanical soil disturbance,
2. permanent organic soil cover, and
3. diversification of crop species grown in sequences and/or associations.

However, while CA which is largely focussed on cropping operations, RA also integrates mixed operations and livestock farming potentially making RA a more inclusive narrative when it comes to promoting soil health and carbon sequestration.



Agroforestry

Agroforestry is the integration of trees and shrubs into crop and animal farming systems. Access to trees encourages livestock to exhibit natural behaviours. Trees also provide access to a range of nutrients. On average, a hectare of woodland locks up more greenhouse gases than a hectare of farmland emits, and using agroforestry can increase land productivity by up to 40% while locking up carbon. On top of this, trees on farms can reduce floods and drought, benefit wildlife and protect the soil. With all of this in mind going forward, agroforestry will be a key way in which the farming community addresses the climate crisis, while starting to build a more sustainable farming future (U.S. Department of Agriculture 2024).

There are three main types of agroforestry:

- Agrisilvicultural systems: combination of trees/shrubs and crops
- Silvopastoral systems: combination of trees/shrubs and grazing of domesticated animals
- Agro-silvopastoral systems: combination of trees/shrubs, animals and crops

The results obtained by implementing agroforestry/principles vary quite widely (Zhu et al. 2019), but there are also significant benefits that can be unlocked. Improved soil water retention, halting of soil erosion, and increased water penetration due to the biomass in the soil (FAO 2025a). The same biomass leads to less leaching and nutrient runoff. Finally, there is an increase the ecosystem’s net carbon sequestration potential and, depending on the kind of tree incorporated into your system, it can also provide an additional revenue stream.

Organic agriculture

Organic farming has been defined as ‘a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects.

Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved’. Certified organic agriculture is regulated by bodies that specify which practices, methods of pest control, soil amendments and so forth are permissible if products are to achieve organic certification.

(Source:

http://www.ifoam.org/growing_organic/definitions/doa/index.html)

Organic agriculture is one of the “purest” forms of CSRA. No synthetic inputs go into the system (e.g. no chemical fertiliser or pesticides). This results in lower net emission levels for the farm, as well as a reduction in nitrogen emissions specifically – both in terms of runoff (Lohr 2002) and gaseous emissions. Limitations are placed on how many animals/ha is allowed, leading to lower emissions per head of livestock. Improved manure management practices are implemented to go along with this.

The result thereof is a lower total energy input per farm, and due to the fact that no synthetic/chemical inputs are used, organically produced products often fetch a higher retail price (Lohr 2002). This results in organic farms often contributing more to local economies.

Permaculture

Despite a high public profile, permaculture has remained relatively isolated from scientific research. Though the potential contribution of permaculture to CSRA transition is great, it is limited by this isolation from science, as well as from oversimplifying claims, and the lack of a clear definition.

The term originated as a portmanteau of permanent agriculture and is defined by co-originator David Holmgren as “consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fibre and energy for provision of local needs”. As a broadly distributed movement with a distinctive conceptual framework for agroecosystem design, permaculture’s relevance to the project of CSRA transition has several aspects. Permaculture can function as a framework for integrating knowledge and practice across disciplines to support collaboration with mixed groups of researchers,

Organic

Definitions

The emphasis of “organic agriculture” is on building humus for soil health, while strictly regulating organic farming systems by not allowing the usage of any synthetic products and GMOs (Shrestha and Horwitz, 2024)

Principles

4 principles developed by the International Federation of Organic Agricultural Movements (IFOAMs):

- health
- ecology
- fairness
- care

Focus on the the well-being of people, the planet, and future generations (IFOAM Organics International, 2024)

Goals

- Organic farming stresses environmental protection, animal welfare, food quality and safety, resource sustainability, and social justice, and use the market to help sustain these aims and pay for internalized consequences (Muhie et al 2022)

References IFOAM Organics International, 2024. (<https://www.ifoam.bio/why-organicshaping-agriculturefour-principles-organic>) Muhie, S.H., 2022. Novel approaches and practices to sustainable agriculture. *Journal of Agriculture and Food Research* 10. 100446. Shrestha, A and Horwitz, D., 2024. Variations and Commonalities of Farming Systems Based on Ecological Principles. *Crops*, 4, 288–307.

Permaculture

Definitions

Consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fibre and energy for provision of local needs (Shrestha and Horwitz, 2024)

Principles - 12 principles

- observe & interact
- catch and store energy
- obtain a yield
- apply self-regulation and accept feedback
- use and value renewable resources and services
- produce no waste
- design from patterns to details
- integrate rather than segregate
- use small and slow solutions
- use and value diversity
- use edges and value the marginal
- creatively use and respond to change (Oberć and Schnell 2020)

Goals

- Bill Mollison’s words “Permaculture is a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labour; and of looking at plants and animals in all their functions, rather than treating any area as a single product system” in (Oberć and Schnell 2020)

References Oberć, B.P. & Schnell, A. (2020). Approaches to sustainable agriculture: Exploring the pathways towards the future of farming. Brussels, Belgium: IUCN EURO. Shrestha, A and Horwitz, D., 2024. Variations and Commonalities of Farming Systems Based on Ecological Principles. *Crops*, 4, 288–307.

stakeholders and land users. Permaculture contributes to an applied form of ecological literacy, supplying a popular and accessible synthesis of complex socioecological concepts. The design orientation of permaculture offers a distinctive perspective that suggests avenues of inquiry in agroecosystem research. Lastly, these factors are embodied in an international movement that operates largely outside of the influence and support of large institutions, which suggests opportunities for participatory action research and the mobilisation of popular inquiry and support (Ferguson and Lovell 2014).

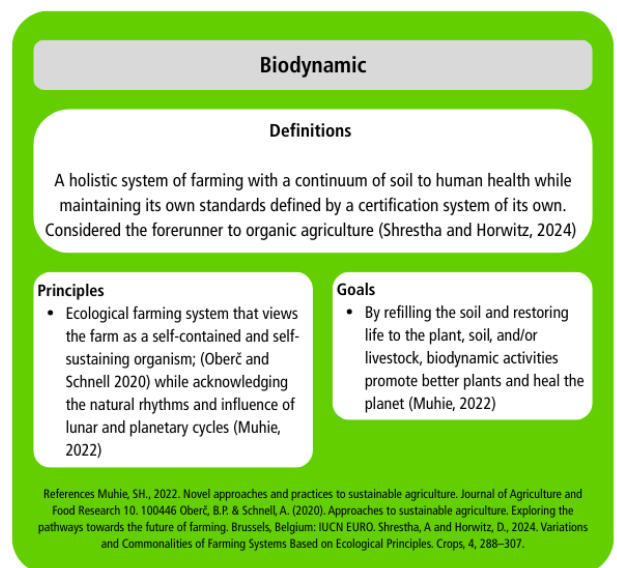
Permaculture is perhaps the most holistic approach to CSRA that has thus far been mentioned. It is defined by 12 principles (Didarali & Gambiza 2019) and three ethics which are: care for people, care for earth, and information sharing. The principles include mimicking the natural environment, the use of mulch and rainwater harvesting, using animal manure as fertiliser and on crop integration (polyculture). Some of the possible benefits of a permaculture system are:

- Improved human health
- Increased resilience to environmental changes
- Reduction of input costs

Biodynamic farming

Biodynamic agriculture is based on the 'holistic understanding of agricultural processes'. It treats soil fertility, plant growth and livestock care as ecologically interrelated tasks, emphasising spiritual and mystical perspectives. Biodynamic agricultural practices include: use of manures and composts instead of artificial chemicals; management of animals, crops, and soil as a single system; use of traditional and development of new local breeds and varieties; the use of an astrological sowing and planting calendar.

(Source: http://en.wikipedia.org/wiki/Biodynamic_agriculture)



ANNEXURE 2: DESCRIPTION OF KEY CSRA PRINCIPLES

Minimum mechanical soil disturbance

Tillage is bad for the soil. It is arguably the most degrading agricultural practice, because any soil disturbance immediately triggers the downward spiral of soil degradation, which starts with the removal of soil cover and the loss of soil organic carbon. What follows are the destruction of soil structure (aggregates) and the collapsing (slaking) of soil pores and channels, leading to compaction and soil surface sealing (crusting), which reduce infiltration, creating much more water runoff and soil loss through erosion.

Tilling the soil with, for example, a plow, disk, chisel plow, ripper, etc., is the equivalent of an earthquake, hurricane, tornado, and forest fire occurring simultaneously to life in the soil (soil life is also called soil biology, the living soil ecosystem or the soil food web). These effects of tillage are destructive and disruptive to the soil food web and creates a hostile, instead of hospitable, place for them to live and work. For example, it disrupts the positive mutualistic relationship between fungi and plant roots, such as Mycorrhizae, by destroying the fine network of root-like structures of the fungi, called hyphae, that scavenge the soil for more free plant nutrients and water. A broken soil food web soon leads to a dead soil with no natural functions and services, which are provided freely by healthy soils. Conversely, no-till/minimum tillage in cropping systems, with appropriate no-till planters, in conjunction with the other regenerative principles and practices, enhances soil aggregation, water infiltration and retention, and carbon sequestration.

The soil may also be disturbed chemically or biologically through the misuse of inputs, such as fertilisers and pesticides. This also disrupts the soil food web, as well as the symbiotic relationship between microorganisms and crop roots. Using the example of Mycorrhizae fungi again – excess phosphorous fertiliser stops the fungi to perform its natural functions, of which one is the mining of phosphorous from soil minerals, making it available to plants for free. By strategically reducing chemical inputs as the soil health improves, we can take advantage of these soil ecosystem services to allow plants to freely access essential nutrients.

Permanent organic soil cover

Soil should always be covered by growing plants and/or their residues (mulches), and soil should rarely be visible from above. A mulch keeps the soil cool and moist which provides favourable habitat for many organisms that begin residue decomposition by shredding residues into smaller pieces. A good soil cover protects it against water and wind erosion, stops water from running off and allows it to infiltrate into the soil.

Diversification of crop species grown

Diversified cropping systems are essential for multiple reasons and could rightly be seen as the driver of regenerative agriculture. The main aim is to maximise photosynthetic capacity, which is the amount of light intercepted by green leaves in a given area (determined by percentage of canopy cover, plant height, leaf area, leaf shape and seasonal growth patterns). Maximum photosynthetic capacity is a

function of crop density and diversity, which means the more different types/species of plants and/or leaves covering as much of the soil surface as possible (ideally 100%) to absorb sun energy, the higher the capacity. On agricultural land, photosynthetic capacity can be improved through the use of multi-species cover crops, crop rotations, animal integration, multispecies pastures and strategic grazing. In parks and gardens, plant diversity and mowing height are important factors. Bare soil has no photosynthetic capacity. Bare soil is also losing carbon (a net carbon source) and is vulnerable to erosion by wind and water. Bare soil increases the temperature and reduces rainfall in the landscape.

Once photosynthetic capacity is increased or maximised a myriad of benefits flow back into the farming enterprise eventually leading to increasing sustainability and profitability. The movement of carbon from the atmosphere to soil (soil carbon sequestration) — via green plants and the process of photosynthesis — represents the most powerful tool we have at our disposal for the restoration of soil health and reduction (drawing down) of atmospheric CO₂ back into the soil replacing it with life-giving oxygen.

Crop diversity, soil cover and a soil carbon sponge restore the small water cycle through higher levels of soil water and higher evapotranspiration rates, which cool down the landscape and increase chances for local rainfall. This is vital to mitigate and reverse the effects of global warming, desertification and erosion triggered by tillage and bare soils.

Higher cropping diversity increases the above-ground biodiversity (e.g. beneficial insects), which increases the potential of any cropping system to reduce disease, pest and weed problems. It is always advisable to compare the costs and benefits of diverse cropping systems (biological control) with the costs and benefits of chemically controlling pests, diseases, weeds, fertility, etc. over the long term.

It is important to understand the premise on which crop diversity is built, which is: Crop diversity (above-ground) → diversity of 'living roots' and their exudates → feeding a diversity of microbes (below-ground) → increasing soil organic carbon → improved soil structure → healthy soils → higher infiltration and soil water-holding capacity, higher natural soil fertility, less compaction → more beneficial insects and pollinators → healthier agro-ecosystems → sustained higher yields, quality and diversity of food with less use of external inputs.

Rotating cereals and legumes in different seasons or alternatively intercropping in the same field. Using multi-specie cover crops in rotations is highly recommended.

Integration of livestock

This principle's aim is to take the effect and benefits of the other principles to an even higher level, implying that the harvesting of sunlight for growing crops and building soils is optimised. Livestock (e.g. cattle, sheep, pigs, chicken, etc.) utilising cover crop mixtures and natural pastures, for example, is part of a natural ecosystem and thereby contributes to diversity. With high density grazing utilising 30–50% of available material (it might be higher in natural pastures), livestock can stimulate root development and recycle 80% nutrients in the form of dung. Retaining adequate leaf area during specific periods of the year reduces the impact of grazing on photosynthetic capacity and enables the rapid restoration of biomass to pre-grazed levels. Over a 12-month period of short, high stocking density grazing cycles followed by an adequate resting period, significantly more and a better diversity forage will be produced — and more carbon sequestered in soil. It is important to remember that the higher the density of animals, the shorter the grazing period and the more uniform the urine/dung distribution will be. This method of organic fertilisation has a major advantage on having to fertilise with inorganic fertiliser. By mimicking original natural grazing patterns of large herds of herbivores (e.g. springboks or blue wildebeest), the key is to utilise smaller areas of pasture and ideally have

multiple daily moves to get the most out of your forage. Regenerative grazing can be extremely effective in restoring soil carbon levels.

Maintenance of a living root as long as possible

There are many sources of food in the soil that feed the soil food web, but there is no better food than the liquid carbon exuded by living roots. This liquid carbon depends on the photosynthetic capacity of the cropping system as explained above. Every plant exudes its own unique blend of liquid carbon, comprising various biological compounds, such as sugars, enzymes and amino acids. Soil organisms feed on this liquid carbon from living plant roots first. Next, they feed on dead plant roots, followed by above-ground crop residues, such as straw, chaff, husks, stalks, flowers and leaves. Lastly, they feed on other organisms lower in the soil food web. The greater the diversity of food for the microbes, especially from living plant roots as their main source, the healthier and more active the soil food web. A healthy soil food web is essential for the provision of multiple functions and services of a healthy soil, such as an increase in plant available nutrients (fertility) and stable soil aggregates (structure or a soil sponge) with a higher infiltration, soil water holding capacity and drought-resilience.

The local context of the farm matters

Every farmer's context is different. Farmers might have differences in natural capital, but they also have different levels of human and financial resources and different values and objectives for their farming enterprises. Although some of these factors might be similar between some farmers, every farmer will eventually have a unique situation or context which he/she understand the best and where he/she are the best, or the only person to influence or change it. Nobody else can do it for them and there are no recipes, only these principles, to work with. Their success to change and adapt these principles in their unique context are determined by their innovation capacity, which is a function of various factors, such as their level of awareness, attitude, knowledge and skills, as well their ability to act. From local and global experiences, the best lesson for farmers is to just do it, starting small, through a trial-and-error process, learning from others, in a life-long journey.

Adapted from Maluleke et al. (2024).

ANNEXURE 3: DESCRIPTION OF KEY CSRA PRACTICES

This section addresses the key practices in relation to the different sustainable and resilient agricultural (CSRA) systems. Tables A3.1 and A3.2 provide further detail, aiming to highlight the differences and similarities between the systems and discusses the cost and benefits of such practices.

Integrated nutrient and pest management

All the agricultural ecological systems aim to minimise the use of synthetic and chemical-based additives to the soil. The overarching sentiment is that having healthy soils eliminates the need for them, thereby reducing their dependencies. For organic agriculture, there are strict rules on what is allowed and not allowed and both organic and biodynamic farming prohibit the use of GMOs. Instead of fertiliser, the systems encourage on-farm fertility through feeding the soil through practices described in sections below and by using organic amendments or natural substitutes such as manure or compost.

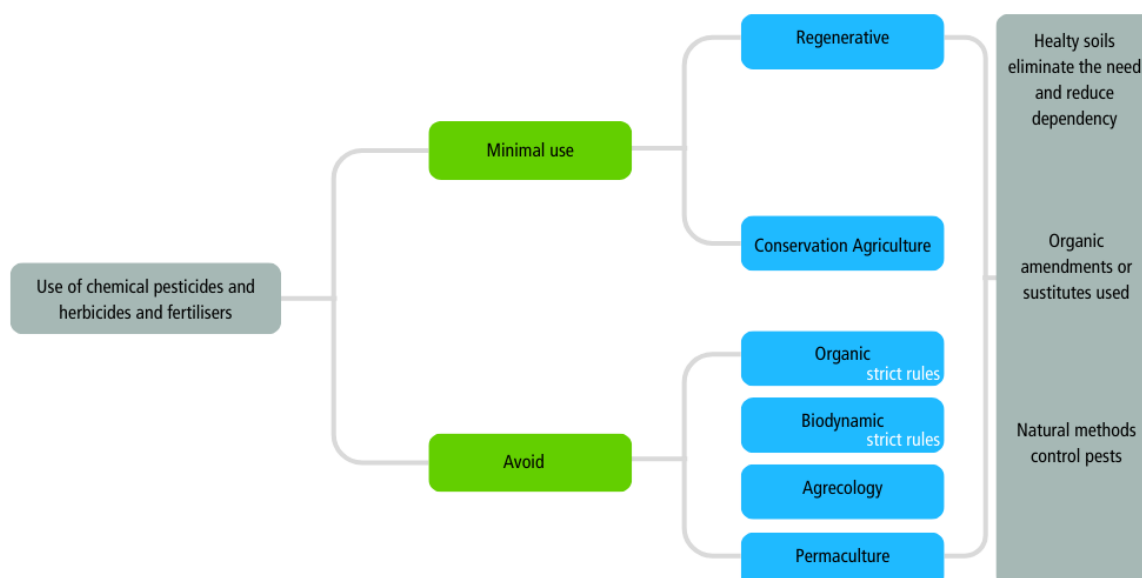


Figure A3.1 Use of chemical additives
Source: Own analysis based on Annexure 3A

Minimal or no-tillage

Tillage breaks up (pulverises) soil aggregation and fungal communities while adding excess O₂ to the soil for increased respiration and CO₂ emission. It can be one of the most degrading agricultural practices, greatly increasing soil erosion and carbon loss. A secondary effect is soil capping and slaking that can plug soil spaces for percolation creating much more water runoff and soil loss. Conversely, no-till/minimum tillage, in conjunction with other regenerative practices, enhances soil aggregation or structure, water infiltration and retention, and carbon sequestration. However, some soils benefit from interim strategic tillage events, such as ripping to break apart hardpans, which can increase root

zones and yields and have the capacity to increase soil health and carbon sequestration. Certain low level chiselling may have similar positive effects.

Minimal soil disturbance is a core principle for both regenerative and conservation-based agriculture and therefore the application of no-till or minimum tillage is adopted. This entails planting systems whereby 30% of the soil surface is covered after planting as this is when the soil surface is most susceptible to erosion from water or wind (SARE 2020). Most of the CSRA systems promote the use of minimum- or no-tillage. For organic and biodynamic farming, tillage is a common tool for soil preparation and weed control and to incorporate organic material; however, it is done minimally and strategically with a focus on preserving soil health and structure.

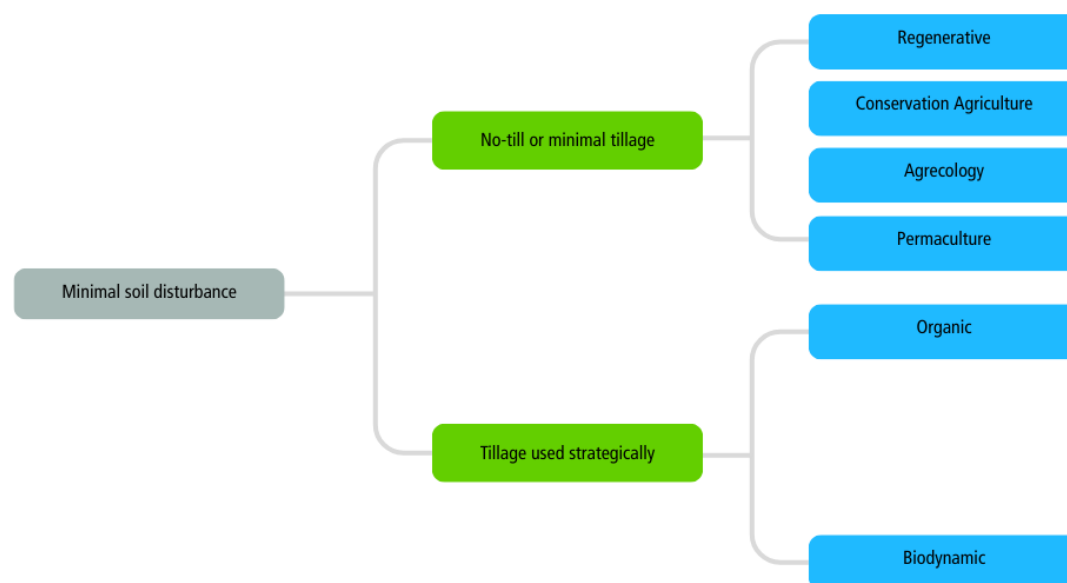


Figure A3.2 *Minimal soil disturbance*
Source: Own analysis based on Annexure 3A

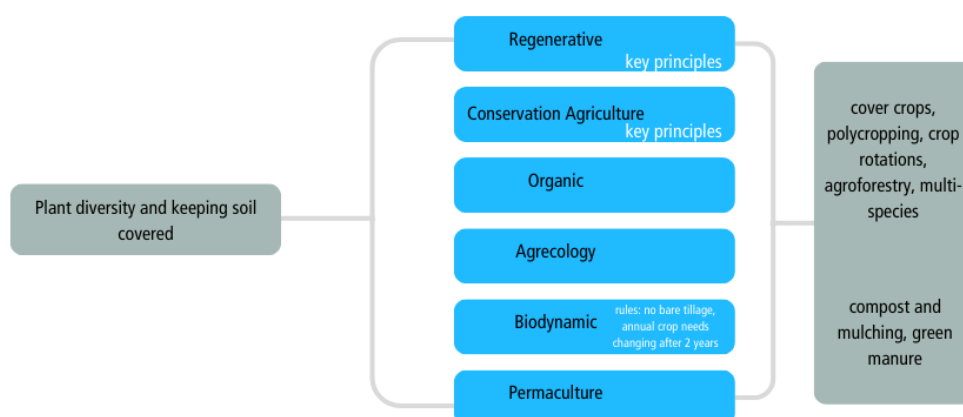


Figure A3.3 *Plant diversity and keeping soil covered*
Source: Own analysis based on Annexure 3A

Diversifying cropping systems, with crop rotations, cover crops and green fallowing

Building biological ecosystem diversity begins with inoculation of soils with composts or compost extracts to restore soil microbial community population, structure and functionality restoring soil system energy (compounds as exudates) through full-time planting of multiple crop intercrop plantings, multispecies cover crops, and borders planted for bee habitat and other beneficial insects. This can include the highly successful push-pull systems. It is critical to change synthetic nutrient dependent monocultures, low-biodiversity and soil degrading practices.

Diversified cropping (mixed associations/multiple cropping/intercropping/crop rotation) imply the growing of two or more plant species in the same field in the same year and at least, in part, at the same time. For the purpose of this document, the term diversified cropping is used, covering all the individual approaches. Diversified cropping permits the intensification of the farm system, which results in increased overall productivity and biodiversity; the recycling of organic material; water management; soil erosion protection; and pest and disease suppression. Integrated legume/grain cropping with livestock production systems will also result in increased overall productivity.

Livestock (animal) integration

Livestock integration in horticulture

Regenerative agriculture's key principle is the integration of livestock which seeks to use this practice to enrich the soils from livestock manure, reducing the need for external fertilisers for crop production and contributing towards a closed loop system. These systems can integrate livestock into perennial systems (orchards or vineyards) with understory grazing or integrating in rotation with pastures or livestock grazing on cover crops or leftover materials after harvesting of crops (Rehberger et al. 2023). Incorporating animals such as cattle, sheep, goats, poultry or pigs into horticultural systems can provide benefits such as natural fertilisation, weed control and pest management. This integration creates a synergistic relationship between plants and animals, leading to more efficient use of resources and increased productivity. It is one of the principles of conservation/regenerative agriculture (Choudhary et al. 2022; Meissner et al. 2013a, b).

The other agricultural ecological systems all promote animal integration to assist with nutrient recycling, land and pest management and improve biodiversity. There is also the further benefit of economic diversification.

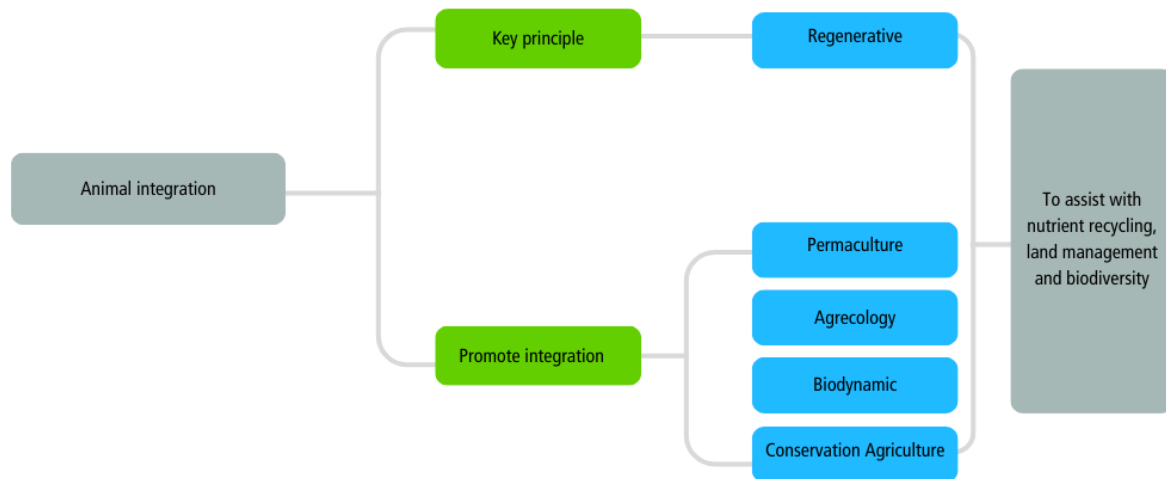


Figure A3.4 Animal integration
Source: Own analysis based on Annexure 3A

Livestock integration in grain crop systems

Integrating livestock into cropland involves using cattle, sheep, goats, chickens or pigs to graze on crop residues or cover crops during fallow periods. It is one of the principles of conservation/regenerative agriculture (Choudhary et al. 2022; Meissner et al. 2013a, b).

Organic livestock farming

Raising animals in a way that adheres to organic standards, which emphasise natural processes, animal welfare and environmental sustainability. Organic food in South Africa is regulated. The Department of Agriculture, Forestry, and Fisheries (DAFF) in South Africa is responsible for overseeing and regulating organic agriculture. The regulatory framework for organic farming is outlined in the “South African Standard for Organic Production and Processing” (SANS 1364; DALRRD 2024a). Key points regarding organic food regulation in South Africa include (DALRDD 2024a):

- **Certification bodies:** The South African organic sector operates with the involvement of accredited certification bodies. These organisations are responsible for inspecting and certifying farms and businesses as organic based on the requirements outlined in SANS 1364.
- **SANS 1364 Standard:** This standard outlines the principles and practices of organic farming and covers various aspects, including soil fertility management, pest and disease control, and the use of organic inputs. It also addresses processing and labelling requirements for organic products.
- **Certification process:** Organic farmers and producers must undergo a certification process to be recognised as organic. This process involves inspections and assessments by accredited certification bodies to ensure compliance with organic standards.
- **Labelling and traceability:** Certified organic products in South Africa are required to meet specific labelling requirements. This includes using the term “organic” only for products that have been certified, and labels must also indicate the certification body.
- **Import and export:** South Africa’s organic regulations also cover the import and export of organic products. Products that are imported or exported as organic must meet the relevant standards and be certified by accredited certification bodies.

Smallholder livestock systems

The management of livestock on a small scale, typically by family farms or individual farmers. These systems are characterised by low input and output levels, reliance on family labour, and integration with other farm activities, all which supports principles of conservation/regenerative agriculture (Geraci et al. 2020).



Figure A3.5 Different livestock production systems in South Africa and their key production principles

Regenerative grazing

Well-managed grazing practices stimulate improved plant growth, increased soil carbon deposits, and overall pasture and grazing land productivity while greatly increasing soil fertility, insect and plant biodiversity, and soil carbon sequestration. These practices not only improve ecological health, but also the health of the animal and human consumer through improved micro-nutrients availability and better dietary omega balances.

Regenerative grazing is managed grazing where the farmer decides where and for how long the animals graze a particular patch of grass. Using this tool, the farmer can manage the under-/overgrazing issue and evenly spread herd impact. The idea is to mimic nature whose grasslands evolved in a symbiotic relationship involving four players – ruminants, predators, grasses and the soil microbiome (Meissner et al. 2013b; FAO 2023). The result of this symbiotic interaction was that the grasslands became one of the dominant biomes of the world and the soils below the grasses the most carbon rich soils on the planet. Grass and soil health were maintained by migrating herds of grazers with the herd effect of the ruminants’ – hooves, mouths, dung and urine – stimulating and fertilising the plant-soil ecosystem (source: <https://www.regenagsa.org.za/regenerative-grazing/>).

Water management

Most of the agricultural ecological systems view water management through the lens of “soil water management”. This means that minimal soil disturbance and good soil management via cover crops, compost and mulches results in improved water use efficiency, increased water infiltration rates and reduced runoff (Strauss et al. 2021). One benefit of higher soil organic matter levels has been water-retention improvements of 30–40% (Mouton 2024a). Some studies suggest that a 1% increase in organic matter can store 150 000 litres of water holding capacity per hectare of soil (Soil Wealth Nurturing Crops 2018).¹⁹

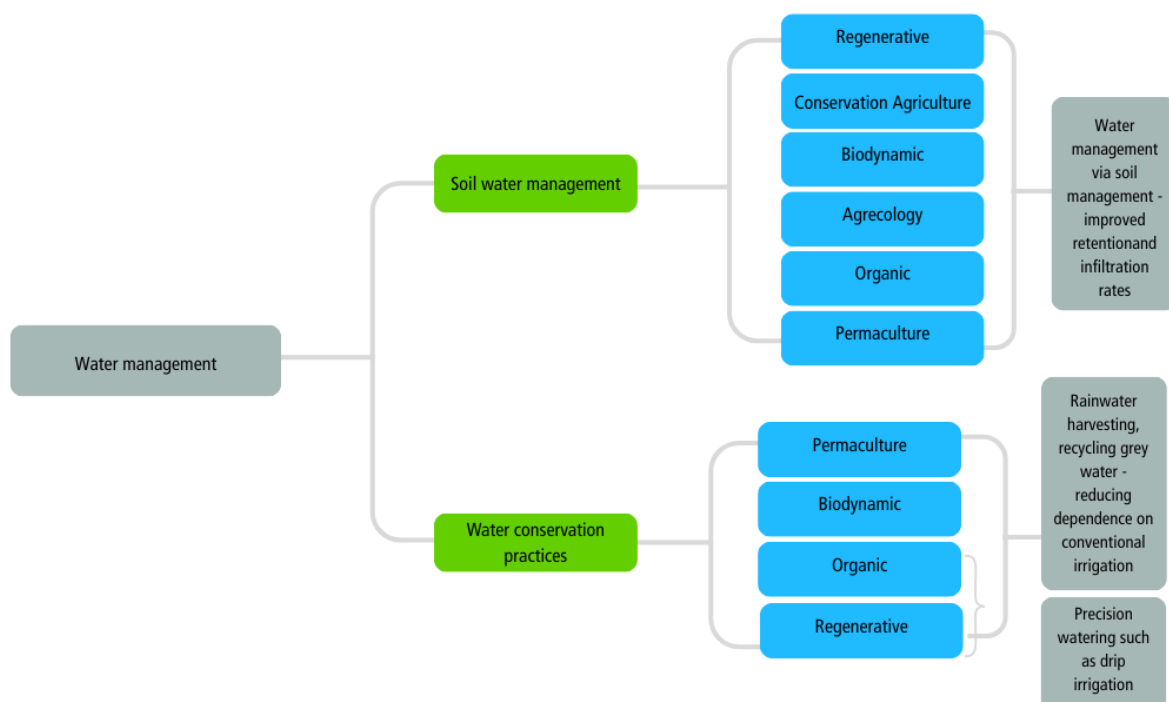


Figure A3.6 Water management
Source: Own analysis based on Annexure 3A

¹⁹ According to many studies, every 1% increase in organic matter (0.58% organic carbon) to a depth of 15 cm can lead to an increase in water holding capacity of 3 000 L/ha to 185 000 L/ha; the latter is assuming organic matter holds about ten times its weight. The actual increase depends on the type of organic matter, soil texture and climate.

The practices also encourage rainwater harvesting and recycling of grey water in order to reduce dependency on water resources. Efficient and precision watering such as drip irrigation is also utilised.

Integrated soil fertility (nutrient) management

Soil fertility is increased in regenerative systems biologically through application of cover crops, crop rotations, compost and animal manures, which restore the plant/soil microbiome to promote liberation, transfer and cycling of essential soil nutrients. Artificial and synthetic fertilisers have created imbalances in the structure and function of microbial communities in soils, bypassing the natural biological acquisition of nutrients for the plants, creating a dependent agroecosystem and weaker, less resilient plants. Research has observed that application of synthetic and artificial fertilisers contribute to climate change through (i) the energy costs of production and transportation of the fertilisers, (ii) chemical breakdown and migration into water resources and the atmosphere; (iii) the distortion of soil microbial communities including the diminution of soil methanotrophs, and (iv) the accelerated decomposition of soil organic matter.

As alternatives to conventional inorganic fertilisers, especially in view of escalating costs, different organic and biological products are increasingly considered. Various new and novel products that are entering the marketplace in increasing amounts also need to be considered as alternative fertilisers. Their efficacy under practical farming conditions needs to be proven, especially in view of the increasing interest in more natural, “biological farming” systems to move beyond the production plateaus, as well as speed up the process of soil improvement, that many CA farmers perceive that have been reached.

Integrated soil acidity management under a CA system should take cognisance of the fact that soil acidification processes are driven by natural or anthropogenic factors. Each of these two factors requires unique soil acidity amelioration strategies. The efficacy of surface-applied lime for correcting topsoil soil acidity, and N fertilisation, are still contentious fertility issues in a no-tillage CA system.

Integrated pest management

Integrated pest management is an ecologically-based approach to pest control combining biological, chemical and other regulatory means. IPM utilises a multi-disciplinary knowledge of crop and pest relationships, the establishment of acceptable economic thresholds for pest populations and constant field monitoring to detect potential problems. It is therefore a strategy to contain pests by biological and cultural control factors, minimising or avoiding chemical control.

IPM methods could include the use of resistant crop varieties, certified seed, protective seed treatments, disease-free transplants or rootstock, crop rotation, push-and-pull systems, cultural practices, removal of infested plant material, and the optimal use of biological control organisms. The farmer has to observe the pest status of the crop and base control decisions on these observations to maintain the delicate balance between pest build-up and natural enemies.

Integrated weed management (IWM)

IWM is normally a combination of practices such as crop rotation and long-term reduced tillage. IWM is a combination of weed control practices, thus reducing dependence on any one type of weed control. Such practices include cultural (crop rotations, intercropping and the use of mulch), mechanical (conservation tillage) supplemented by chemical herbicides (such as Glyphosate) where needed.

Rainwater harvesting

According to Kahinda and Taigbenu (2011), rainwater harvesting (RWH) is a general term which describes the concentration, collection, storage and use of rainwater runoff for both domestic and agricultural purposes. This practice involves capturing rainwater from surfaces like rooftops, land surfaces and rock catchments, and then storing it in tanks, cisterns or reservoirs. The collected water can be used for various purposes, including irrigation, drinking and recharging groundwater.

Rainwater harvesting is crucial for several reasons, particularly in regions like South Africa where water resources are often limited. Here are some key benefits:

- **Mitigates water scarcity:** By collecting and storing rainwater, communities can have a reliable source of water during dry periods, reducing their dependence on surface and groundwater resources.
- **Controls soil erosion:** Rainwater harvesting helps to control soil erosion by reducing the volume of surface runoff. This is particularly important in agricultural areas where soil erosion can lead to reduced crop yields and loss of fertile soil.
- **Improves groundwater levels:** Harvested rainwater can be used to recharge groundwater aquifers, helping to maintain and improve groundwater levels. This is especially important in regions where groundwater is the primary source of water for drinking and irrigation.

More CSRA practices for decision makers (from Lotter, Stronkhorst and Smith 2009)

Vegetation strips

Vetiver grass soil conservation system
Grass strips

Grazing land management

Rangeland rehabilitation
Veld restoration on degraded duplex soils
Chemical bush control
Rip-ploughing, oversowing
Combating of invader plants and push packing
Agronomic and vegetative rehabilitation

Revegetation and re-seeding
Communal grazing management
Restoration of degraded rangeland
Rehabilitation techniques in southern Kalahari – vegetative and management

Erosion control/rehabilitation

Contours
Old motor tyre contours
Gully control (gabions)
Gravity type inverted tyre structure

Terraces

Traditional stone terrace walls

Ground water/salinity regulation/water use efficiency

Sub-surface drainage on irrigated lands

Storm water control/road runoff

Water run-off control plan on cultivated land

Other

Wetland rehabilitation
Strip mine rehabilitation by plant translocation
Manuring/composting/nutrient management
Rotational system/shifting cultivation/fallow/slash and burn/multiple cropping
Agroforestry
Afforestation and forest protection
Water quality improvement
Sand dune stabilisation
Coastal bank protection
Protection against natural hazards

Certifications

There are only internationally recognised certificates in place for biodynamic and organic farming systems. The regenerative and conservation systems are adaptable and context-specific and often incorporate several different sustainable agriculture approaches. Permaculture has very specific design rules to follow but no certifications or standards in place. There is an agroecology platform in

South Africa that is working to have a South African framework adopted as an approach to transform our food systems into becoming more sustainable and resilient (Leippert et al. 2020).

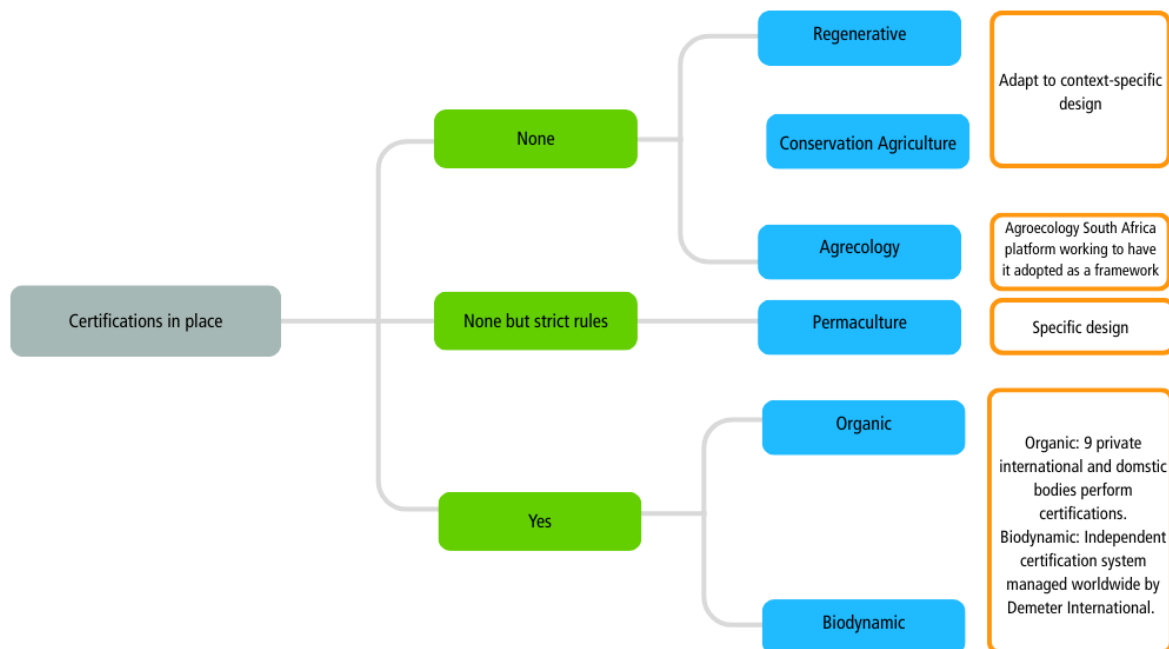


Figure A3.7 Systems of certification
Source: Own analysis based on Annexure 3A

There are about 250 certified organic commercial farms in South Africa which is estimated to be 50 000 hectares. South Africa is also home to hundreds of non-certified organic farmers (generally small-scale farmers) who follow organic principles and market their products informally through farmers markets (Zylem n.d.). For biodynamic farming, the independent certification system is managed worldwide by Demeter International. Products can be regulated and monitored at every stage of the inspection and verification process. Reyneke Wines is the first certified biodynamic wine farm and Wupperthal Original Rooibos Cooperative, the world's only Demeter-certified rooibos farm (BDAASA). To encourage co-operation and knowledge exchange, Demeter initiated a Participatory Guarantee System whereby producers evaluate each other against the Demeter standards as its benchmark.

ANNEXURE 3A: A comparative analysis of different sustainable and resilient agricultural systems

Table A3.1: Definitions and principles

Concepts	Year of origin	Definition	Principles	Goals/Outcomes
Regenerative	1980s	Regenerative agriculture encompasses numerous definitions. Schreefel et al. (2020) define it as “an approach to farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting ecosystem services, with the objective that this will enhance not only the environmental, but also the social and economic dimensions of sustainable food production” (Shrestha and Horwitz 2024)	Five overarching principles: 1. Reduce tillage 2. Never leave bare soil 3. Maximise plant diversity and productivity on farm 4. Integrate livestock and cropping systems 5. Reduce or eliminate synthetic agrichemicals (Kabenomuhangi 2024) Dependent upon one another within a system for them to be optimally successful. (Fenster et al. 2021)	1. Improve soil health, including, the capture of carbon (C) to mitigate climate change 2. Promote biodiversity while producing nutritious food profitably (Giller et al. 2021)
Agroecology	1928	Agroecology can be considered as a science, a farming practice and a social movement (Oberč and Schnell 2020) Agroecology is the integration of research, education, action and change that brings sustainability to all parts of the food system: ecological, economic, and social. (Shrestha and Horwitz 2024)	Based on 12 principles 1. recycling 2. input reduction 3. soil health 4. animal health 5. biodiversity 6. synergy 7. economic diversification and the co-creation of knowledge 8. social values and diets 9. fairness 10. connectivity 11. land and natural resource governance 12. participation (Wezel et al. 2020)	Boost the resilience and the ecological, socio-economic and cultural sustainability of farming systems while seeking a new way of considering agriculture and its relationship with society (Oberč and Schnell 2020)
Organic	1940	The emphasis of “organic agriculture” is on building humus for soil health, while strictly regulating organic farming systems by not allowing the usage of any synthetic products and GMOs (Shrestha and Horwitz 2024)	4 principles developed by the International Federation of Organic Agricultural Movements (IFOAMs): 1. health, 2. ecology, 3. fairness, and 4. care, for the well-being of people, the planet, and future generations (IFOAM Organics International 2024)	Organic farming stresses environmental protection, animal welfare, food quality and safety, resource sustainability, and social justice, and use the market to help sustain these aims and pay for internalised consequences (Muhie 2022)
Permaculture	1978	“Consciously designed landscapes which mimic the patterns and relationships found in nature, while yielding an abundance of food, fibre and energy for provision of local needs” (Shrestha and Horwitz 2024)	3 ethics 1. Earth care, People care, Fair share 12 principles: observe & interact, catch and store energy, obtain a yield, apply self-regulation and accept feedback, use and value	Bill Mollison’s words “ <i>Permaculture is a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labour; and of</i>

			renewable resources and services, produce no waste, design from patterns to details, integrate rather than segregate, use small and slow solutions, use and value diversity, use edges and value the marginal, and creatively use and respond to change (Oberč and Schnell 2020)	<i>looking at plants and animals in all their functions, rather than treating any area as a single product system” (Oberč and Schnell 2020)</i>
Biodynamic	1924	A holistic system of farming with a continuum of soil to human health while maintaining its own standards defined by a certification system of its own (Shrestha and Horwitz 2024) Considered the forerunner to organic Agriculture (Muhie 2022)	Ecological farming system that views the farm as a self-contained and self-sustaining organism (Oberč and Schnell 2020) while acknowledging the natural rhythms and influence of lunar and planetary cycles (Muhie 2022) 1. individuality of farm 2. “living ground” 3. Biodynamic preparations 4. compost and compost preparation (Demeter website in Oberč and Schnell 2020)	By refilling the soil and restoring life to the plant, soil, and/or livestock, biodynamic activities promote better plants and heal the planet (Muhie 2022)
Conservation agriculture	1990	Conservation agriculture is a set of management principles aimed at reducing the impact of conventional agricultural practices on the environment, while still maintaining profitability and food security (FAO 2011 in Strauss et al. 2021)	3 principles: 1. minimum soil disturbance, 2. diversity through crop rotation and 3. permanent organic soil cover (Strauss et al. 2021)	Conservation agriculture aims to “keep the soil together” as a living ecosystem that enables food production and helps address climate change (Oberč and Schnell 2020)

Table A3.2: Practices and applications

Practises/ Principles	Regenerative	Conservation	Organic	Biodynamic	Agroecology	Permaculture
Minimise use of fertilisers, pesticides and herbicides	Healthy soil eliminates the need for fertilisers. Minimise or eliminate agrochemicals or use of organic amendments as substitutes such as compost, compost tea, and manure (Oberč and Schnell 2020)	Promoting application of fertilisers, pesticides, herbicides and fungicides in balance with crop requirement. Aims to feed the soil rather than fertilise the crop. This will reduce dependence on chemicals.	Strict rules: Prohibition of the use of GMOs; no use of ionising radiation; Limiting the use of artificial fertilisers, herbicides and pesticides to the minimum. No use of mineral nitrogen fertilisers (Oberč & Schnell 2020). Use resistant varieties and breeds and techniques encouraging natural pest control.	No use of fertilisers or pesticides, synthetic chemicals or GMOS. (Muhie 2022). Using biological controls as last resort; approach pests & diseases holistically (Oberč and Schnell 2020)	Natural methods to control pests, reducing dependence on chemicals & synthetic fertilisers and purchased inputs. Eliminate agrochemicals in production systems, along with other technologies that pose a risk to human and environmental health, such as genetically modified crops and insects (SAFCEI 2023).	No chemical and synthetic fertilisers or pesticides (Oberč and Schnell 2020).
Soil health	Absolutely key principle	Promote soil health through the 3 CA principles.	Very important - “feed the plant by feeding the soil” principle (Shrestha and Horwitz 2024).	Biodynamic agriculture promotes soil health by adding spiritual and ritual components such as enlivening compost with biodynamic principles and biodynamic sprays (Oberč and Schnell 2020).	Secure and enhance soil health and functioning for improved plant growth, particularly by managing organic matter and enhancing soil biological activity.	Designs a scheme to maximise soil health: Building healthy soil (Shrestha and Horwitz 2024).
Minimal soil disturbance	Key principle: Minimise soil disturbance: 1. No-till/minimum tillage to enhance soil aggregation, water infiltration and retention, and carbon sequestration. Preserves fungal & bacterial biodiversity underground (Shrestha and Horwitz 2024).	Core principle: Minimising soil disturbance, which entails reduced or no tillage (through direct seed and/or fertiliser placement) (Strauss et al. 2021).	Tillage is a common tool in organic farming for soil preparation, weed control and incorporating organic material (Gruver and Wander 2009).	Tilling is still a practice used in biodynamic farming, but it is often done minimally and strategically, with a focus on preserving soil health and structure. Lunar and cosmic rhythms are considered when planning and soil preparations used. (Demeter website)	Conservation tillage: no or minimum tillage improves soil structure and organic matter (Oberč and Schnell 2020).	No-tilling, mulching, cover crops in order to build healthy soil (Oberč and Schnell 2020).

Plant diversity, cover crops and soil cover	Key principle of no bare soil, having living roots all year around and increasing diversity (Oberč and Schnell 2020). Practises include composting, intercropping, multi-species cover crops – using crop covers for soil microbiome diversification by providing constant vegetal cover on the land's topsoil (Shrestha and Horwitz 2024).	Keeping soil covered and incorporating a wider range of plant species is a key principle. Practises include growing cover crops, leaving crop residues, crop rotations on land post-harvest and mulching. Crop rotations allow producer to break the pest & disease cycles (Strauss et al. 2021).	Diversification of species, breeds or varieties – polyculture, crop rotations, companion crops and green manure crops to restore the fertility of the soil. Establishment or maintenance of semi-natural habitats (Oberč & Schnell 2020).	Utilises cover crops to adding plant diversity and crop rotation to increase diversity in soil. Utilises heirloom seeds. Bare tillage year-round is prohibited so land needs to maintain adequate green cover. No annual crop can be planted in the same field for more than two years in succession (Biodynamic Certificate standards Demeter website).	Mixing crops such as intercropping improve nutrient and input efficiency, better use of space & help with pest control. Fallowing and crop rotation: life cycle of pests interrupted. Cover crops and mulching: provide nutrients to soil, reduce erosion (Oberč and Schnell 2020). Encourage the use of local and improved crop varieties.	Principles “catch and store energy” include practises of organic mulch application, “Integrate rather than segregate” includes polyculture and “use and value diversity” includes increasing plant species diversity. “Use edges and value the marginal” applies to high field border density (Reiff & Bach 2018). Promotes biodiversity through companion planting (Shrestha and Horwitz 2024).
Animal integration	Key principle is the integration of crop-livestock systems to improve soil health through managed grazing (Giller et al. 2021). Provides synergies through integrating crops & livestock (Shrestha and Horwitz 2024).	Expanded to include the integration of livestock into cropping systems. Although not initially incorporated, benefits include increased diversification, financial stability and profitability (Swanepoel 2021).	Integrating animal husbandry into crop producing farms is one of the principles of organic farming (FAO). Livestock management that focuses on animal welfare (open fields) and sustainable pasture management (Oberč and Schnell 2020).	Treats farm as a living organism. Integrate crop and livestock to supporting the creation and uptake of vital nutrients. (Oberč & Schnell 2020). Breeding livestock tailored to unique farm (Shrestha & Horwitz 2024).	Crop-livestock integration: allowing for optimal nutrient recycling, assist in economic diversification (Oberč & Schnell 2020).	Utilises animals for multiple for functions: land management, pest control, weed and soil nutrient management, food & fibre production (Oberč and Schnell 2020).
Water Management	Soil water management – improved infiltration rates and water holding capacity (Giller et al. 2021).	Water management via “soil water management”: minimal soil disturbance results in water use efficiency and soil cover increases water infiltration rates and reduced runoff (Strauss et al. 2021).	Water management via soil management. Employment of precision watering such as drip irrigation and rainwater harvesting are practised (Hasan et al. 2024).	Use methods that conserve natural resources, including groundwater. Less nitrate pollution due to better stocked farms, soil has better absorption and storage	Key principle is to practice good water management to enhance soil moisture and limit water movement (Pollard & Du Toit 2019). Efficient water harvesting (Oberč and Schnell 2020).	Managing water flow through keyline design. Utilises mulches, rainwater harvesting, and recycling greywater (Shrestha and Horwitz 2024).

				capacity (Demeter, n.d.).		
Certification	No certification standards. Adapt to context-specific design and incorporate a number of different sustainable agriculture approaches.	No certification or specific rules.	In SA, private international and domestic bodies perform certification: 9 certification bodies. Draft National Policy on Organic Production – which has not progressed for almost a decade. Globally, 2.8 million farmers practising in 2018 (Muhie 2022).	Independent certification system managed worldwide by Demeter International Products can be regulated and monitored at every stage of the inspection and verification process. Holistic Demeter’s standards are higher than those of nations. Conducted on 202 000 ha globally as of 2019 (Demeter n.d.).	No certificate or approved standard. In SA, there is an Agroecology South Africa platform comprising of more than 70 organisations ²⁰ working to have agroecology adopted as a framework for agriculture in the country (SAFCEI 2023).	Specific design: provides a guide to the design, implementation and maintenance of the system (Shrestha and Horwitz 2024).
Social welfare			Stresses food quality and safety and social justice (Muhie 2022). IFOAM (International Federation of Organic Agriculture Movements): “Health, Ecology and Fairness and Care” (Shrestha and Horwitz 2024).	Contributing to social and economic health: biodynamic farmers pioneered ‘community supported agriculture’ (Oberč and Schnell 2020).	As a social movement, agroecology provides a solution to malnutrition by delivering a greater diversity of foods with higher nutritional content (SAFCEI 2023). Social and political movement of food systems. Build food systems based on culture, identity, tradition of local communities (Wezel et al. 2020).	Whole systems design includes the people – 3 ethics of permaculture: earth care, people care and fair share (Permaculture Principles). Practitioners share values and exchange knowledge, conscientious of human rights and meets ‘fairness through provisioning food justice’ (Shrestha and Horwitz 2024).

²⁰ These include Biowatch, the Environmental Monitoring Group (EMG), the Seed and Knowledge Initiative (SKI), the African Centre for Biodiversity, SAFCEI

Economic considerations	CA/RA aims to actively restore systems to a new state of improved productivity rather than just economic viability (Shrestha and Horwitz 2024).	Lower input costs, increased yields resulting in economic benefits.	Price premiums on organic produce necessary to cover the more initial expensive organic production costs. Questioned whether high prices be maintained if becomes mainstream (Oberč and Schnell 2020). Yet, produces consistent yields while maintaining ecological integrity (Muhie 2022).	Economic sustainability of biodynamic farming in question – if there is enough demand for biodynamic goods and paid a premium (Singh 2024).	Encourages economic diversification. Through diversity on-farm incomes giving farmers more financial independence and value addition opportunities while enabling them to respond to demand from consumers (Wezel et al. 2020).	Promoting local communities, reducing reliance on imported food, creating community services. Commercial scalability in question (Oberč and Schnell 2020).
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ANNEXURE 4: Part A, Grain crops

A4.1 Summer grains

Table A4.1 *Definitions of grains*

Grain	Definitions
Cereals	Maize, wheat, grain sorghum, barley, millet and buckwheat
Oilseeds	Sunflower seed, soya beans, canola, castor beans, groundnuts, linseed, cotton seed & safflower seed
Maize	White maize, yellow maize, lesser-known types of maize (including waxy maize, popcorn, sweet corn and bread maize)
Wheat	Bread wheat, soft wheat, and durum wheat and wheat products (which refers to commodity derived from the processing of wheat or into which wheat or any part of wheat has been converted)
Grain Sorghum	The seed of any sorghum except a broom sorghum, hay sorghum or cane sorghum
Barley	Gluten free, high fibre cereal plant of the grass family <i>Poaceae</i>

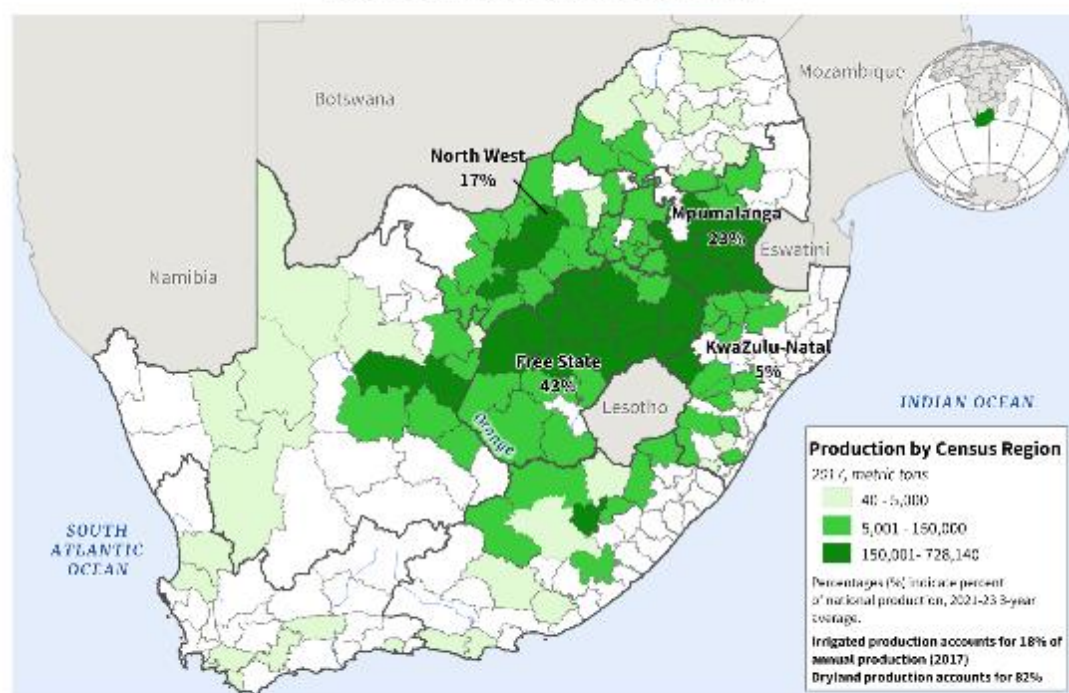
Source: AgriSETA (2024)

A4.2 Summer grains

The following figures show the distribution as well as volume over time of the summer grains planted across South Africa, as discussed in Chapter 1.

Figure A4.1 illustrates the so called “maize quadrangle” in the Free State and North West provinces where up to 70% of the country’s maize is produced (Strauss et al. 2021). The area planted (Figure A4.2) has remained relatively constant, while both the yield and harvest value trend upwards, with a slight drop in yield in 2022/23.

South Africa Corn Production



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Source: South Africa Crop Estimates Committee, Department of Agriculture, Land Reform, and Rural Development, 2023.
South Africa 2017 Census of Commercial Agriculture.

Figure A4.1 Maize production map

Source: USDA (2025)

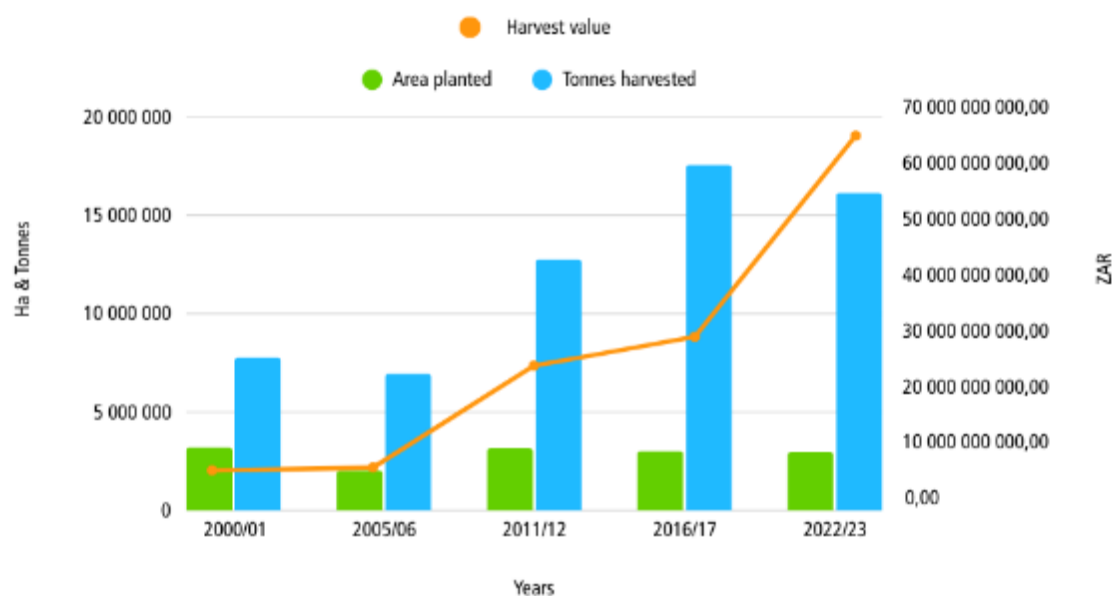


Figure A4.2 Maize production and harvest information

Source: DALLRD (2024)

Sunflowers are primarily produced in the Free State and North West provinces. The yield and area trends match each other, but there is a steady increase in crop value over the last 20 years (see Figures A4.3 and A4.4).

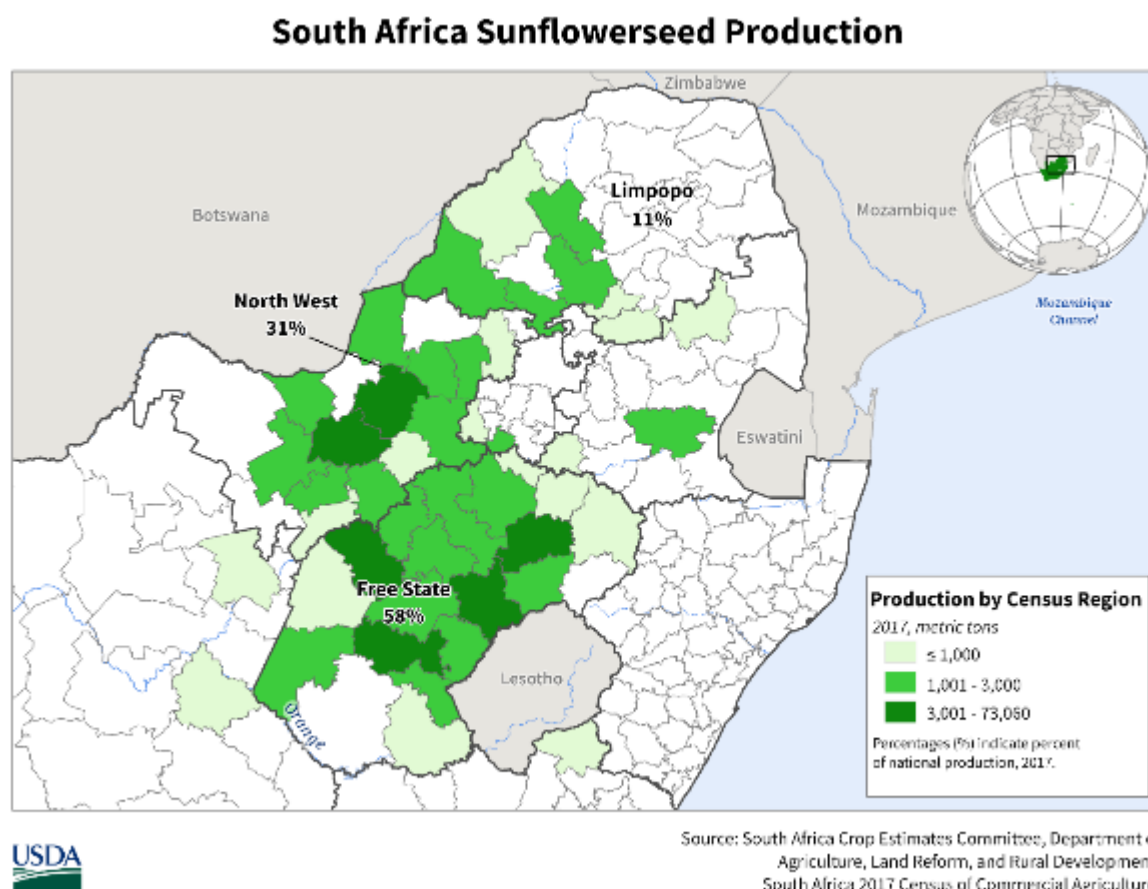


Figure A4.3 Sunflower seed production map
 Source: USDA (2025)

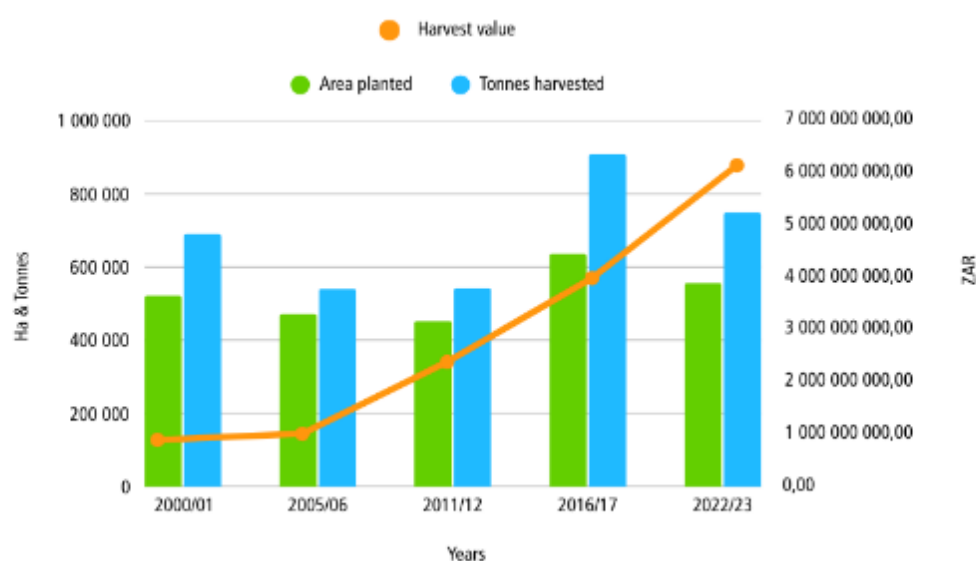
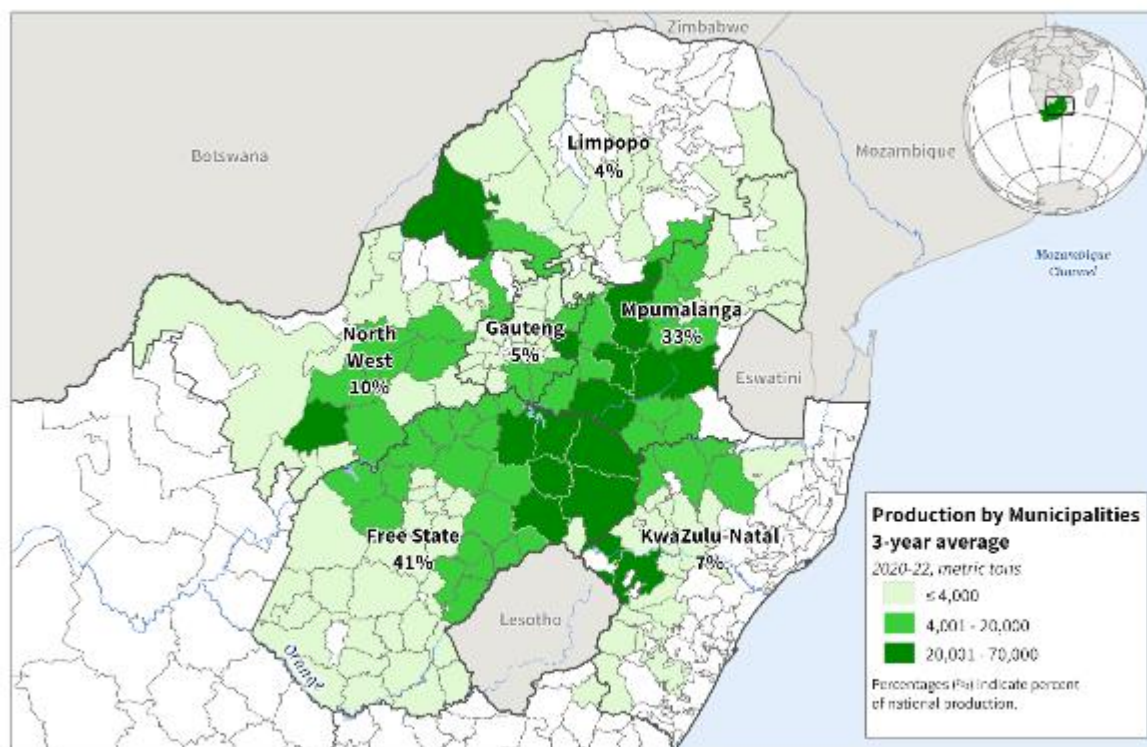


Figure A4.4 Sunflower seed production and harvest information
 Source: DALLRD (2024)

Figures A4.5 and A4.6 show a massive growth in the value of soybeans, matched by the area planted but especially by yield. Soybeans are primarily produced in the eastern Free State, Mpumalanga and North West provinces.

South Africa Soybean Production



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Source: South Africa's Department of Agriculture, Land Reform & Rural Development (DALRRD), 2023.

Figure A4.5 Soybean production map
Source: USDA (2025)

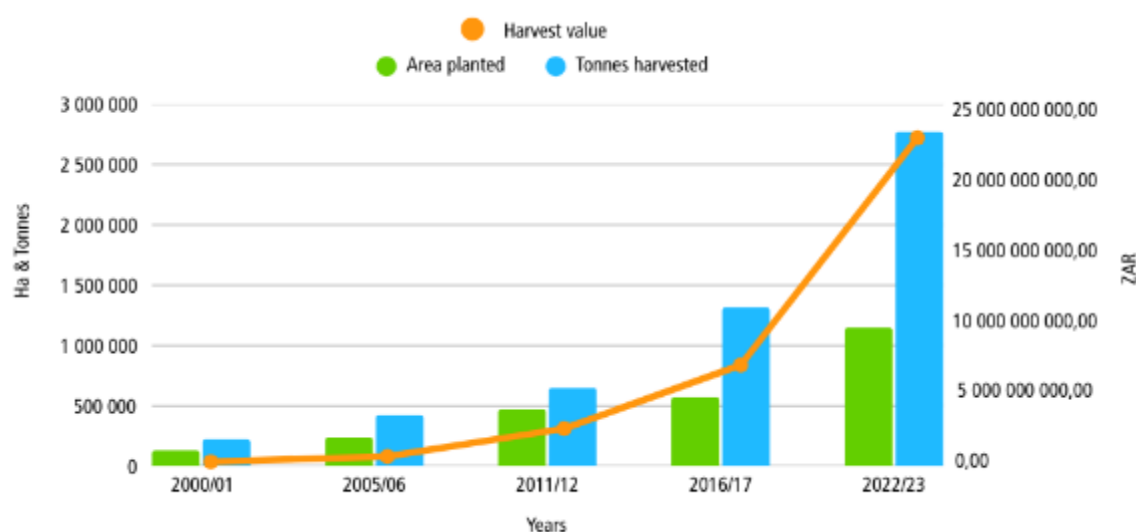
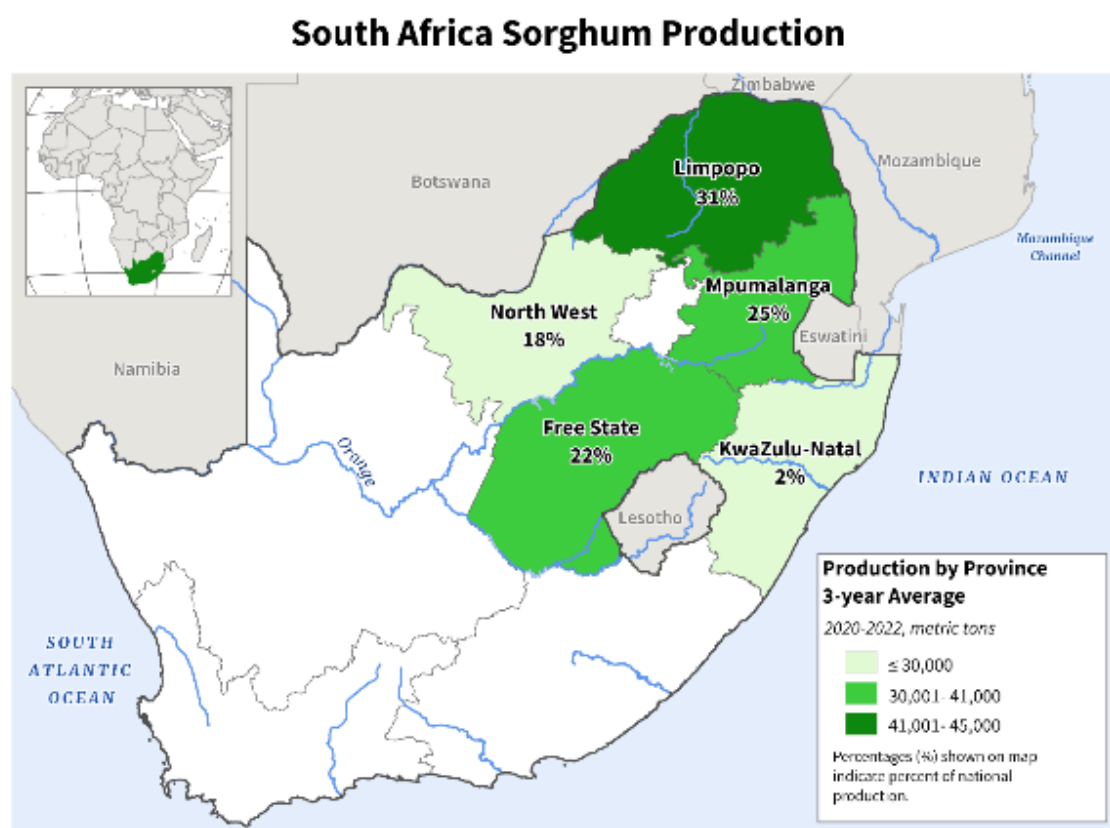


Figure A4.6 Soybean production and harvest information
Source: DALLRD (2024)

Figure A4.7 shows that the value placed on Sorghum is slowly decreasing over time. Not just by the drop in price between 2016/17 and 2022/23, but also by the area planted that has steadily been declining since 2000/01 (Figure A4.8).



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Source: Sorghum Production estimates from South Africa's Crop Estimates Committee, Department of Agriculture, Forestry & Fisheries, 2022.

Figure A4.7 Sorghum production map

Source: USDA (2025)

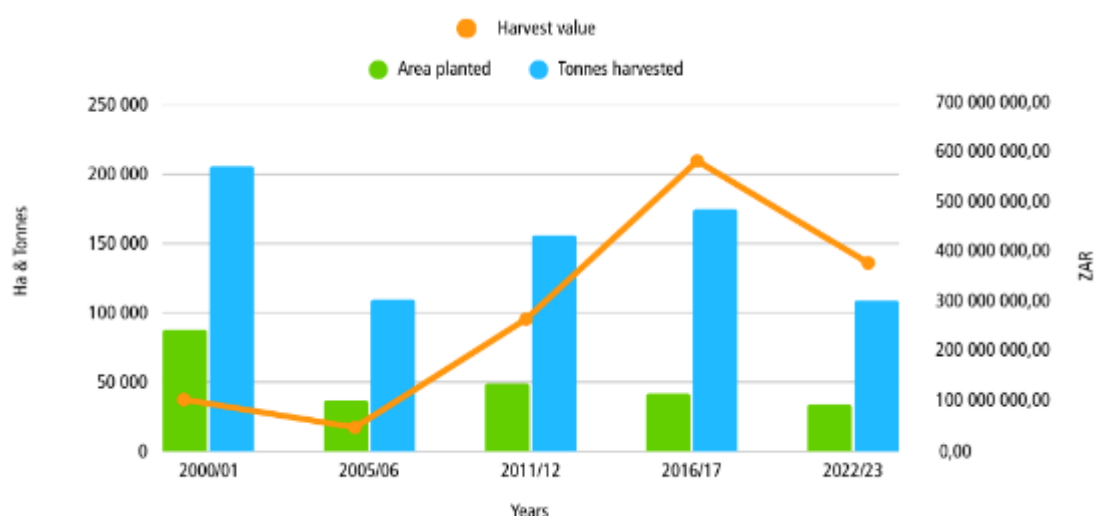


Figure A4.8 Sorghum production and harvest information

Source: DALLRD (2024)

A4.3 Winter grains

The following figures show the distribution and volume of winter grains planted across South Africa.

Figures A4.9 and A4.10 show the distribution of wheat production, where the split between winter and spring wheat is clear. In the Western Cape province where most wheat is produced it is grown during winter, while in the Free State and North West provinces it is spring wheat, planted before soil temperatures rise too much to allow for germination and a good growing season.

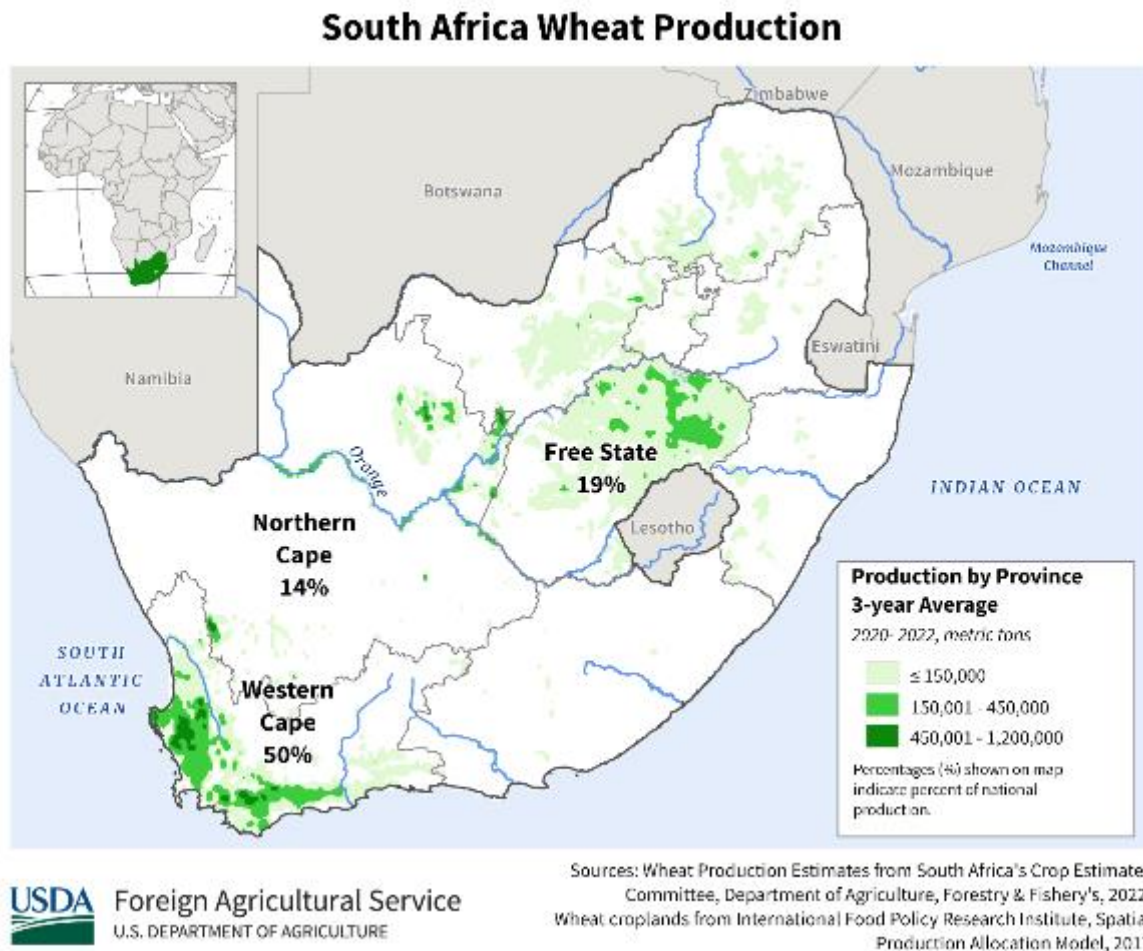


Figure A4.9 *Wheat production map*
Source: USDA (2025)

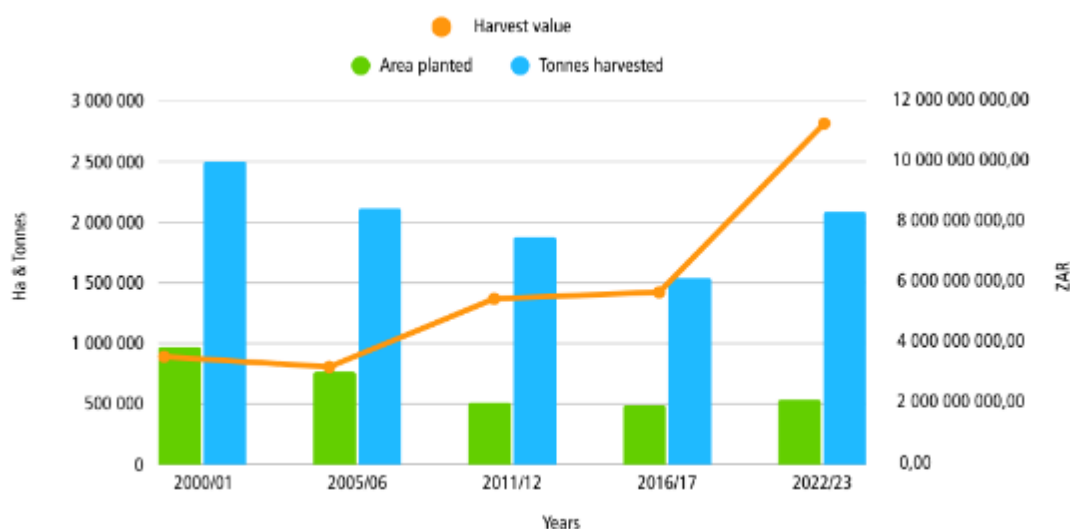


Figure A4.10 Wheat production and harvest information
Source: DALLRD (2024)

The trends in canola production (Figures A4.11 and A4.12) are similar to those observed in soybeans. There is steady growth observed in both yield and area planted, with a significant increase in the monetary value of the harvest.

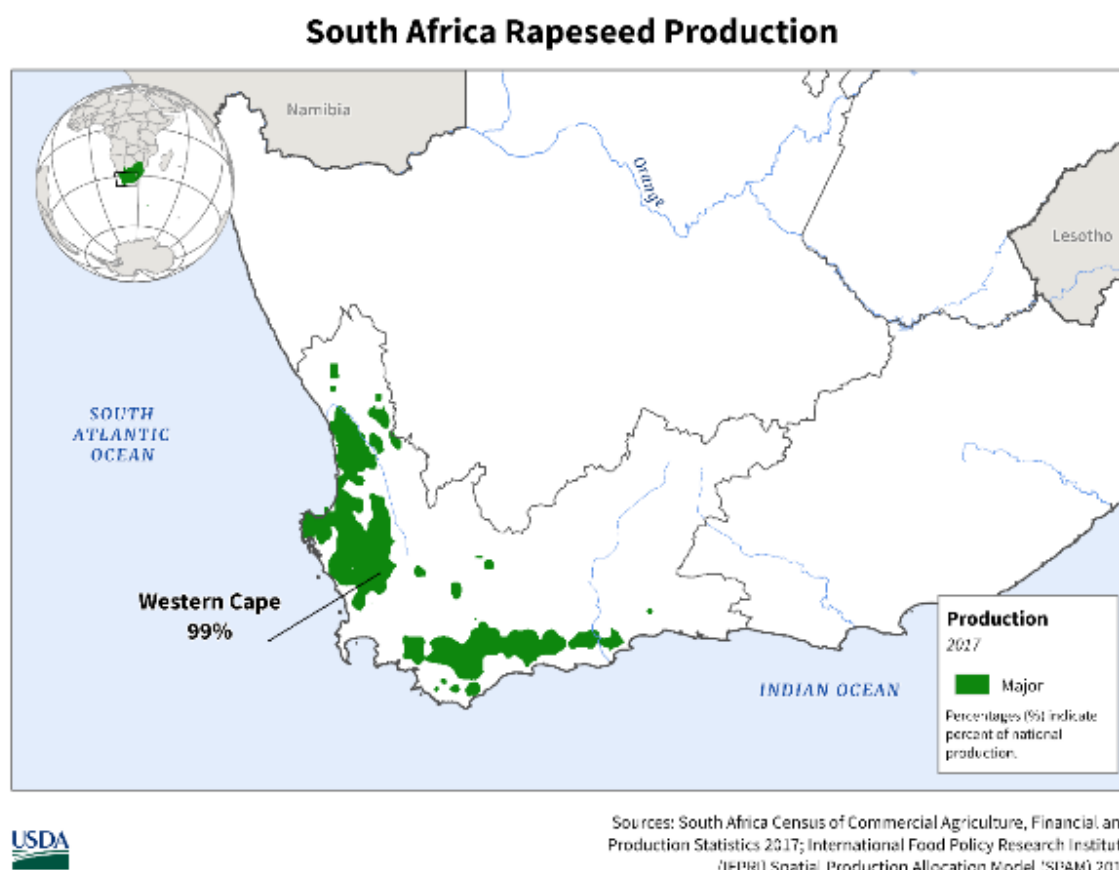


Figure A4.11 Canola production map
Source: USDA (2025)

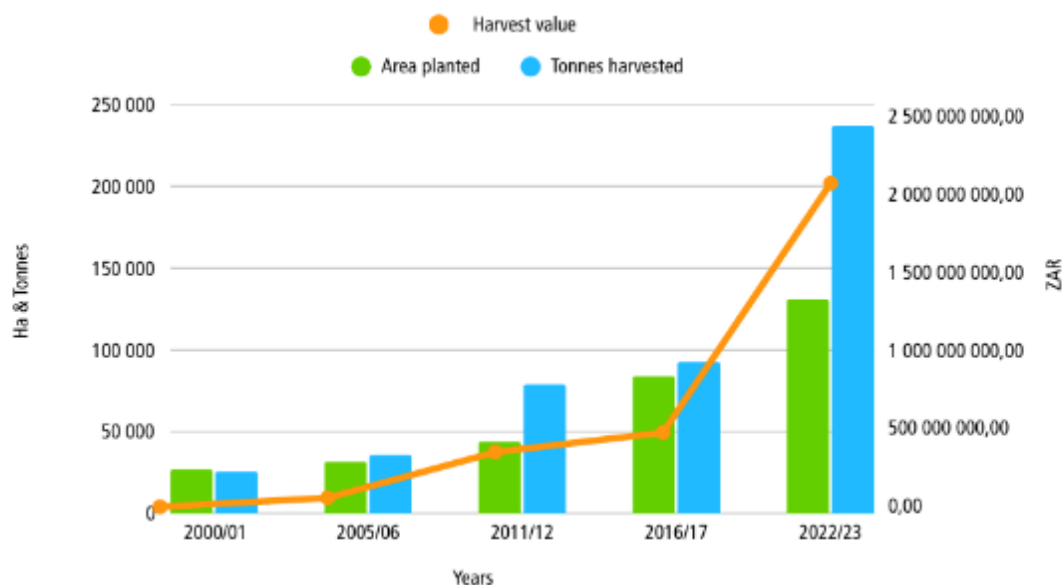
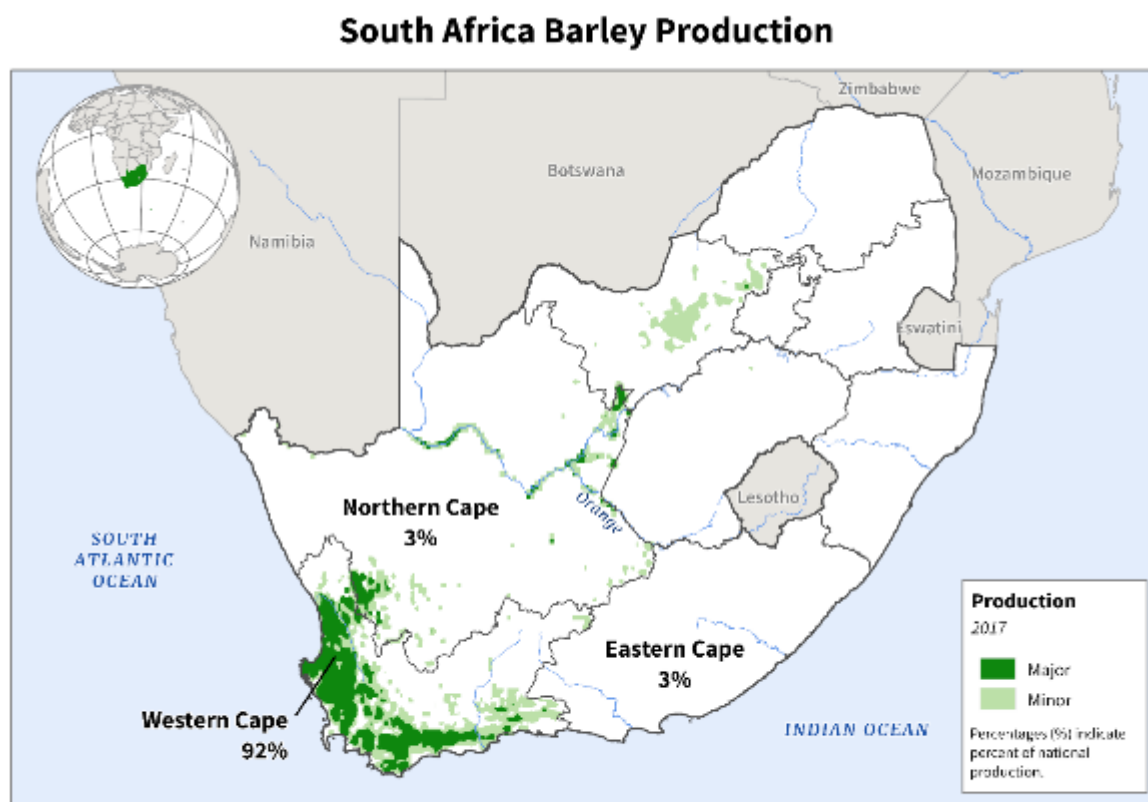


Figure A4.12 Canola production and harvest information
Source: DALLRD (2024)

Barley (see Figures A4.13 and A4.14) is almost exclusively produced in the Western Cape province, and while the area planted has remained more or less constant, there is a steady increase in both yield and harvest value.



Sources: South Africa Census of Commercial Agriculture, Financial and Production Statistics 2017; International Food Policy Research Institute (IFPRI) Spatial Production Allocation Model (SPAM) 2017

Figure A4.13 Barley production map
Source: USDA (2025)

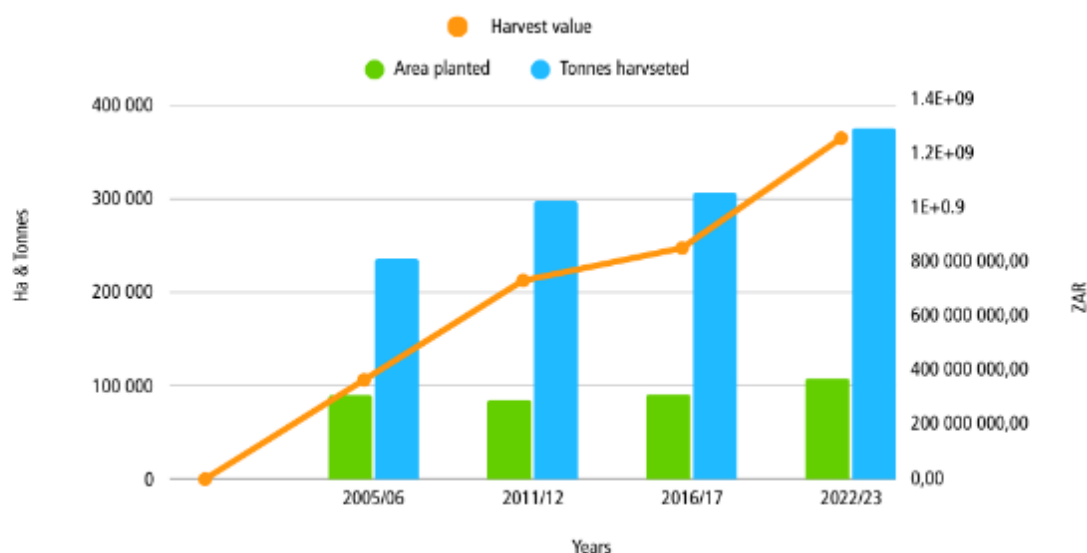


Figure A4.14 Barley production and harvest information
Source: DALLRD (2024)

A4.4 Grains: Exports and Imports

Considering first exports, where does the maize go? As shown in Figures A4.15 and A4.16, most of the yellow maize exports go to the Far East, while Botswana, Italy and Mexico are the main clients for white maize (SAGIS 2025).

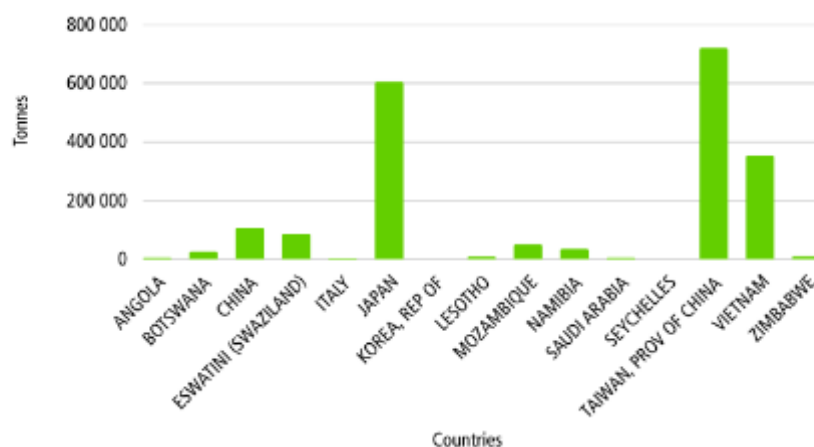


Figure A4.15 Yellow maize exports

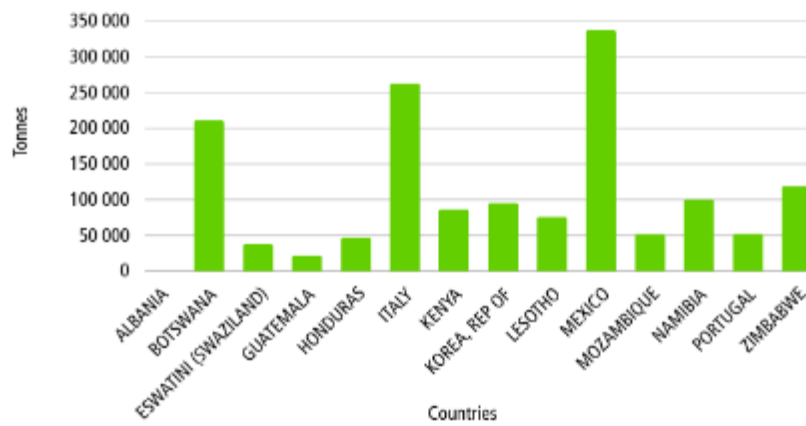


Figure A4.16 White maize exports
Sources: SAGIS (2025)

Considering wheat as the main import among the commodities represented – apart from maize during the 2015–16 El Niño-induced drought crisis (Ainembabazi et al. 2018) – the following figures illustrate where it is imported from. Also, a quick look at the national wheat exports shows that it is limited to countries in Southern Africa, as Figures A4.17 and A4.18 illustrate.

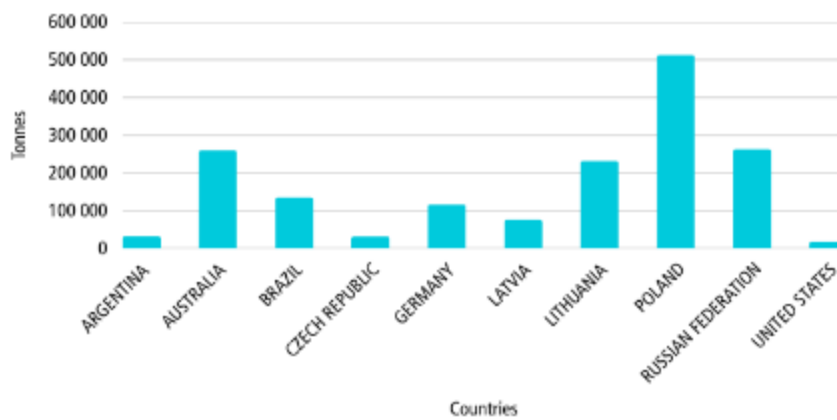


Figure A4.17 Where South Africa imports its wheat from

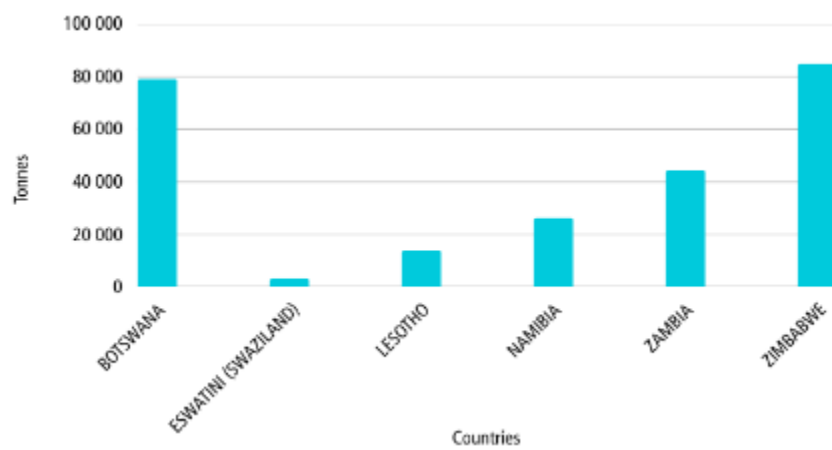


Figure A4.18 The countries buying wheat from South Africa
Sources: SAGIS (2025)

ANNEXURE 5: Livestock production in South Africa: Production areas, trends, consumption, market structure, trade of different sectors

A5.1 Beef cattle

There is a clear difference between formal (commercial) and informal (non-commercial) beef sectors (DALRRD 2023a). The commercial beef sector is well-developed and mature and the second fastest growing commodity in the agricultural sector, with South Africa being the top beef producer on the continent. South Africa has a large cattle population spread across various regions with significant areas dedicated to grazing and feedlots. Approximately 80% of South African agricultural land is suitable for extensive grazing (DALRRD 2023a). The production of weaners for the feedlot industry is the main form of cattle farming – feedlots account for approximately 75% of all beef produced in the country (DALRRD 2023a, 2024b).

There are various breeders' organisations representing most international and indigenous cattle breeds. Most of the organisations are affiliated with the South African Studbook and Animal Improvement Association. The Milk Producers' Organisation (MPO) is the most prominent producer organisation in the South African dairy sector. The Red Meat Producers' Organisation (RPO) and the National Emergent Red Meat Producers' Organisation (NERPO) represent producers in the commercial and emerging agricultural sectors, respectively (DALRRD 2023a).

Cattle are found throughout the country, but mainly in Eastern Cape, KwaZulu-Natal, Free State and North West as seen in Figure A5.1. Herd sizes vary according to type of cattle (DALRRD 2023a).

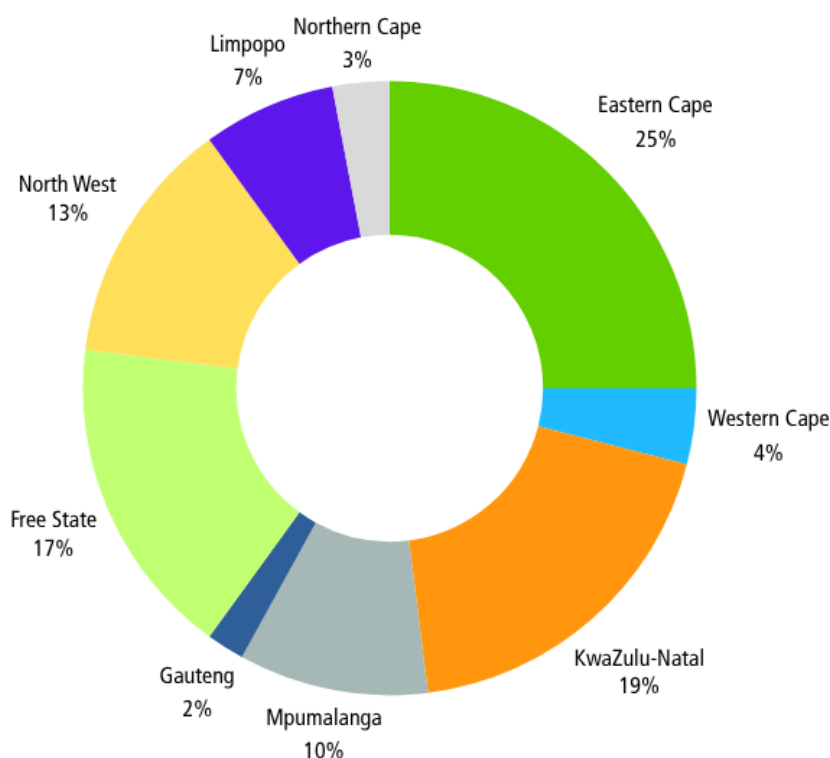


Figure A5.1 Provincial distribution of all cattle, 2023
Source: DALRRD (2023a)

The total number of cattle in South Africa (Figure A5.2) decreased with 50 million from August 2023 to August 2024 and was estimated at 12 149 million at the end of August 2024, comprising of various international dairy and beef cattle breeds in addition to indigenous breeds such as the Afrikaner and the Nguni. Beef cattle contribute approximately 80% to the total number of cattle in the country, while dairy cattle make up the remaining 20%. Holstein-Friesian, Jersey, Guernsey and Ayrshire are the four major dairy breeds found in South Africa (DALRRD 2023a, 2024b; ARC 2024).

The amount of beef produced depends on the infrastructure such as feedlots and abattoirs, not necessarily by the number of cattle available in those areas. South Africa has highly developed transport infrastructure that allows movement of cattle and calves from one area to another, even from other neighbouring countries. South Africa currently has approximately 430 abattoirs slaughtering cattle, pigs and sheep on an annual basis. Approximately 40% of all slaughtering is performed by abattoirs that may slaughter an unlimited number of animals (Class A) and highly regulated abattoirs (Class A & B) slaughter approximately 60% of cattle. Most of these abattoirs have linkages with feedlots (DALRRD 2024b; ARC 2024).

The gross value of beef production increased from R20.5 billion in 2012/13 to R37 billion in 2017/18. In 2018/19, beef gross value experienced a slight decline of 7%. This was caused by the Foot and Mouth Disease outbreak in 2019. The gross value increased through to

2022/23. The average gross value of beef produced during this period amounted to R32.9 billion per annum (DALRRD 2024b; ARC 2024).

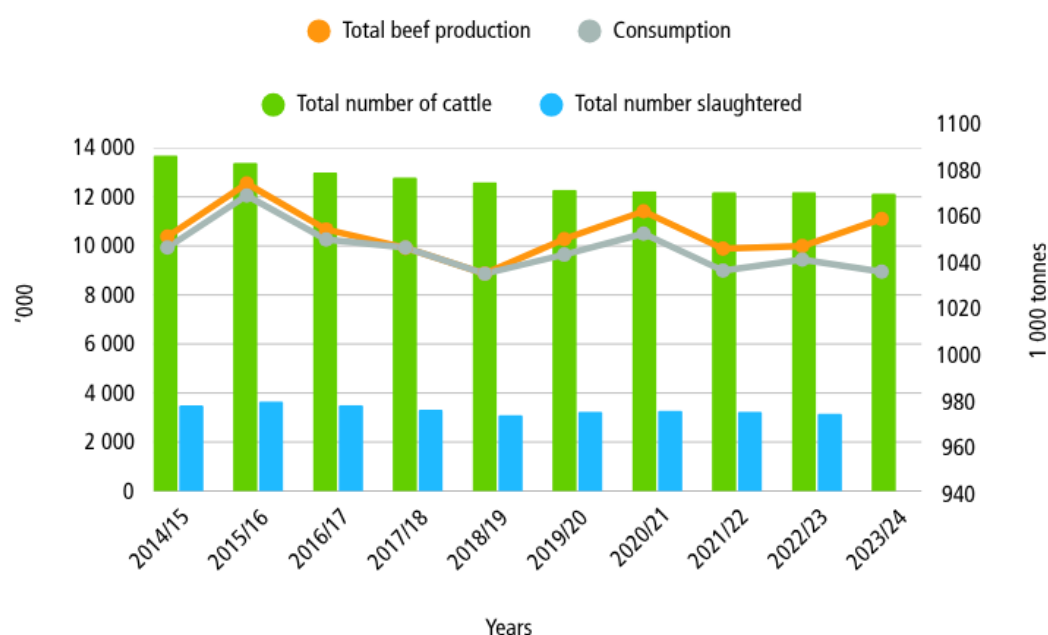


Figure A5.2 Total number of cattle, number slaughtered and beef production and consumption (in thousand tonnes), 2014/15–2022/23

Sources: DALRRD (2023a, 2024b); Western Cape Government (2024); RMIS (2024, 2025c)

South Africa's beef production remains below its 2016 peak but has been rising, increasing from 700 776 tonnes in 2022 to an expected 777 706 tonnes in 2024. This growth is driven by higher slaughter numbers and gains in average slaughter weights. Total slaughters reached just under 2.6 million in 2023 and are projected to approach 2.8 million in 2024, a year-on-year increase of 7.3%. Herd rebuilding between 2019 and 2022, and live imports from Namibia and Botswana, mostly by the feedlot sector, has supported this rise, although it has pressured prices (DALRRD 2024b; RMIS 2025c).

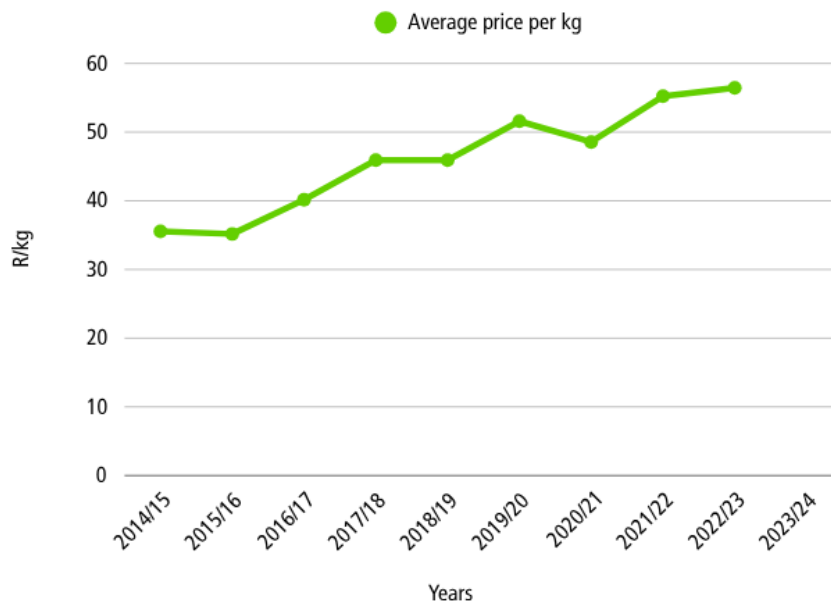


Figure A5.3 Average beef producer price per kg (Rand), 2014/15–2022/23
 Sources: DALRRD (2023b, 2024b); RMIS (2024); Western Cape Government (2024)

The producer price of beef increased by 92% in the past decade (Figure A5.3). In 2024, retail prices have been decreasing in alignment with the increased production and constrained consumer spending power in South Africa. The A2 price (Figure A5.4) has moved mostly sideways but is now showing signs of decline – following the reduction in weaner prices, which reflects the increased volume of weaner imports from Namibia, followed by a reduction in live cattle imports from Botswana as seen in Figure A5.5 (DALRRD 2024b; RMIS 2024, 2025a).

A2 price



Figure A5.4 Average A2 prices for beef, 2021–2023
 Source: RMIS (2024)

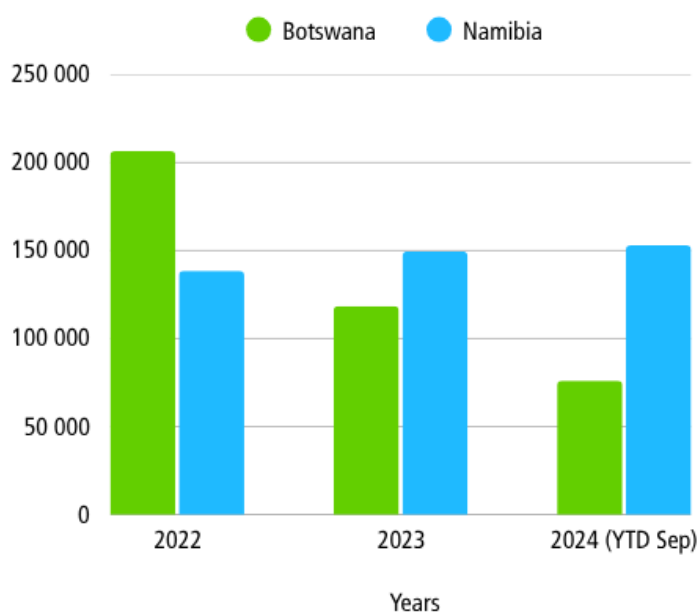


Figure A5.5 Live cattle imports (number of cattle) into South Africa, 2022–2024
Source: RMIS (2024)

The imports peak was realised in 2013 and declined over the years until it reached the minimum in 2020 (Figure A5.6), which recorded a 91% decrease. The decline in imports emanated from a tremendous decrease in beef imports from Namibia and Botswana as they both account for 80% share. The chunk of imports is mostly frozen beef which accounted for around 80% throughout the period analysed. South Africa imported 3 913 tonnes of beef worth R169 million in 2024, thus a decrease of 19% in value and 26% in quantity from the previous year (DALRRD 2023a, 2024b; RMIS 2024).

The decrease in exports in 2021 and 2022 (Figure A5.6), among other reasons was caused by another food and mouth disease outbreak. South Africa exported approximately 38 000 tonnes of beef in 2024 yielding an export value of R3.7 billion year. This represents an increase of 36% in the quantity and increase of 32% in the value of beef exported from 2023 to 2024 year (DALRRD 2023a, 2024b; RMIS 2024). The average import and export prices of beef between 2017 and 2024 can be seen in Figure A5.7.

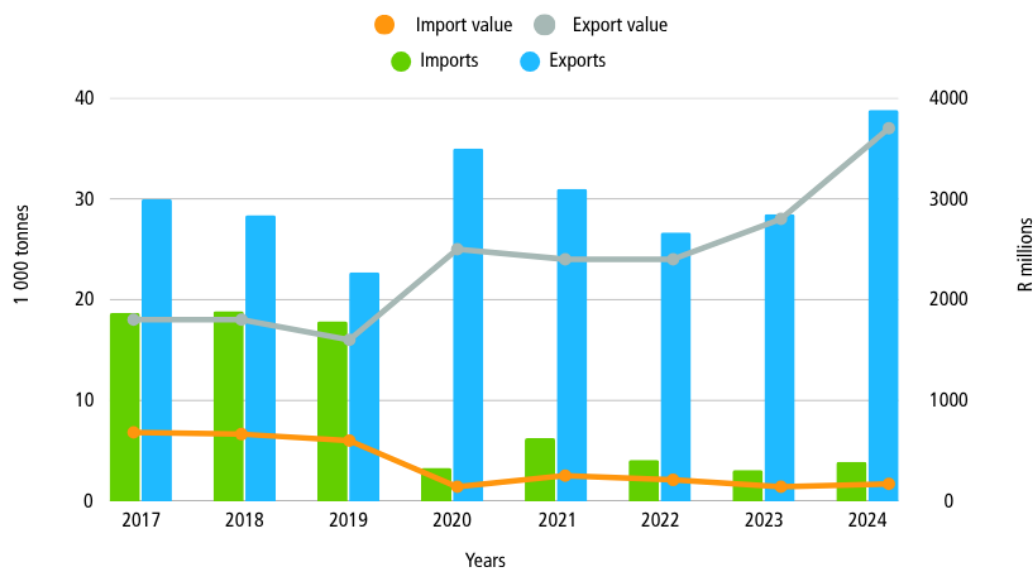


Figure A5.6 Beef import and export quantities (thousand tonnes) and value (R million), 2017–2024
 Sources: DALRRD (2023a, 2024b); RMIS (2024, 2025a)

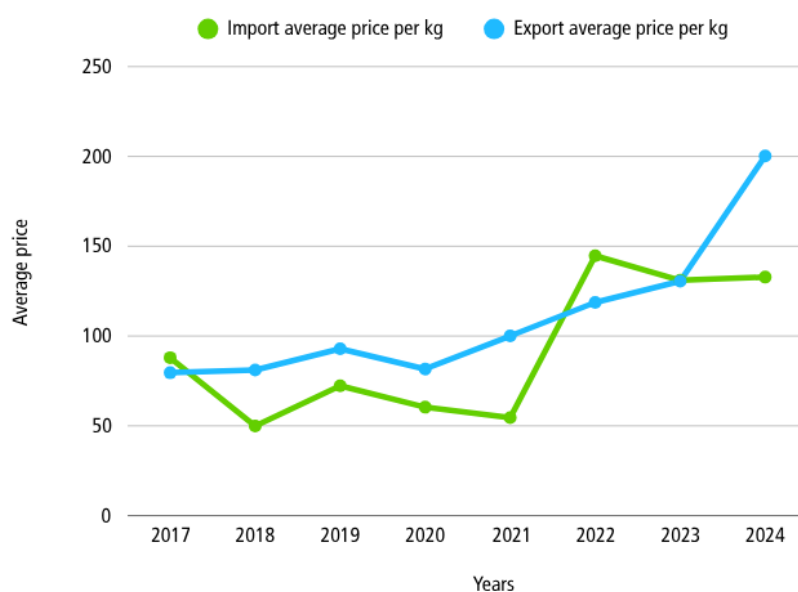


Figure A5.7 Average import and export price of beef per kg (Rand), 2017–2024
 Sources: DALRRD (2023a, 2024b); RMIS (2024, 2025a)

A5.2 Dairy cattle

Dairy farming is a major agricultural industry, employing thousands of people and producing milk for both local consumption and export (MilkSA 2024). Dairy farming is widespread, concentrated largely in the coastal regions because of their mild temperatures and good rainfall conditions; which assures good quality, natural and artificial pastures (MilkSA 2024;

ARC 2024). Certifications include organic farming and sustainable practices. South Africa exports dairy products to various international markets (DALRRD 2024b; MilksSA 2024).

Important organisations involved in the dairy sector of South Africa include:

- Milk South Africa (MilkSA)
- The South African Milk Processors' Organisation (SAMPRO)
- The Milk Producers' Organisation (MPO)

As seen in Table A5.1, the Eastern Cape was the largest milk producer and accounted for 29.5% of the total commercial milk production, followed by Western Cape (28.3%), KwaZulu-Natal (28.3%) and Mpumalanga (4.5%) (DALRRD 2024b; MilkSA 2024).

The primary dairy sector

The number of milk producers in South Africa decreased by 1.0%, from 891 in January 2023 to 882 in January 2024, and decreased by 35% from January 2018 to January 2023. Milk production decreased by 2.1% from 3 411 000 tonnes in 2018 to 3 339 000 tonnes in 2023. Milk production per producer on the other hand increased by 52% between 2018 and 2023 (MilkSA 2024). The gross value of milk produced in 2022, including milk for the producer's own consumption and on-farm usage, increased by 12.4% and amounted to R23 797 million, compared to R21 170 million in 2021 due to higher producer prices (DALRRD: Directorate Statistics and Economic Analysis 2023; MilkSA 2024).

Table A5.1 *Unprocessed milk production and producers per province, 2024*

	Milk production (%)	Number of dairy producers
Eastern Cape	29.5	164
Western Cape	28.3	299
KwaZulu-Natal	28.3	182
Mpumalanga	4.5	35
Gauteng	4.4	46
Free State	3.2	91
North West	1.4	57
Limpopo	0.4	5
Northern Cape	0	3

Source: MilkSA (2024)



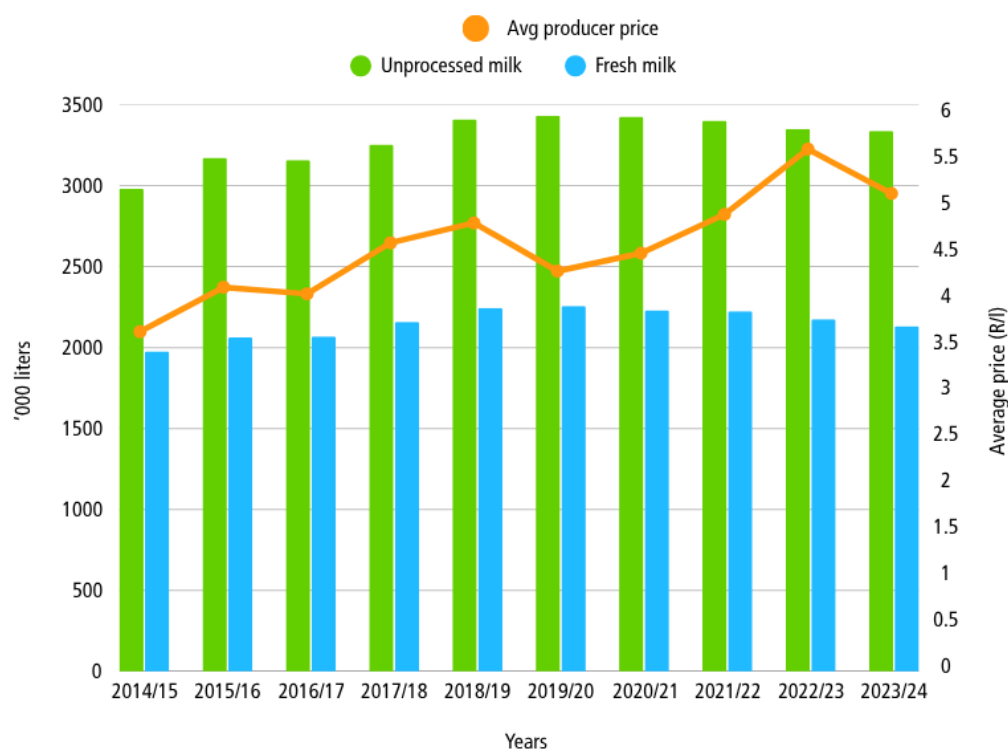


Figure A5.8 Annual unprocessed milk production vs fresh milk consumption, 2014–2023
 Sources: DALRRD: Directorate Statistics and Economic Analysis (2023); SAMPRO (2024a)

Annual unprocessed milk production shows a steady linear upward trend over time (Figure A5.8). For the last four years, unprocessed milk production has been suppressed compared with the overall trend. Total unprocessed milk to market for 2023 was 3 339 272 tonnes, which is 0.32% down from the previous year. The average producer price of milk showed an upward trend since 2020 despite slower growth in demand and output levels (MilkSA 2024; SAMPRO 2024b). The average producer price according to DALRRD for 2023/24 was R5.06 per litre, 9.3% lower as opposed to R5.53 per litre in 2022/23 (DALRRD: Directorate Statistics and Economic Analysis 2023; MilkSA 2024).

The secondary dairy industry

This industry consists of a few large processors operating nationally, a growing number of processors who operate in more than one region, many smaller processors who operate in specific areas, and several milk producers who sell their own produce to retailers and consumers – known as producer-distributors (PDs). From January 2023 to January 2024, the number of PDs decreased from 62 to 54, a decrease of 12.9%; milk processors decreased by

3.8% over the same period (see Table A5.2). The number of PDs decreased by 39% from 88 (2018) to 54 (2024). The number of milk processors decreased by 9% from 138 in 2018 to 125 in 2024 (MilkSA 2024).

Table A5.2 *Total number of producers-distributors (PDs) and processors (Proc) per province, 2018–2024*

Total number of producers-distributors (PDs) and processors (Proc) per province														
Total	2018		2019		2020		2021		2022		2023		2024	
	Proc	PDs	Proc	PDs	Proc	PDs	Proc	PDs	Proc	PDs	Proc	PDs	Proc	PDs
	138	88	160	110	131	77	133	67	136	67	130	62	125	54

Source: MilkSA (2024)

*Milk processors refer to producers of processed milk and manufacturers of other dairy products. Producer-distributors are individuals who predominantly sell unprocessed milk produced by their own dairy animals to consumers, and/or sell it to retailers, and/or use such milk for processing and/or the manufacturing of dairy products, and/or sell it to individuals outside the jurisdiction of South Africa, and/or move it outside the jurisdiction of South Africa.

Production and consumption of dairy products in SA

Cow numbers vary widely among producers. The average number of cows in a herd range from zero in the Northern Cape to 1 285 in the Eastern Cape. The average milk production per cow per day was 16.1 litre in 2023. Ninety-nine per cent of unprocessed milk was delivered to the market. The estimated dairy market composition in 2022 was 61% liquid products and 39% concentrated products (MilkSA 2024; SAMPRO 2024d).

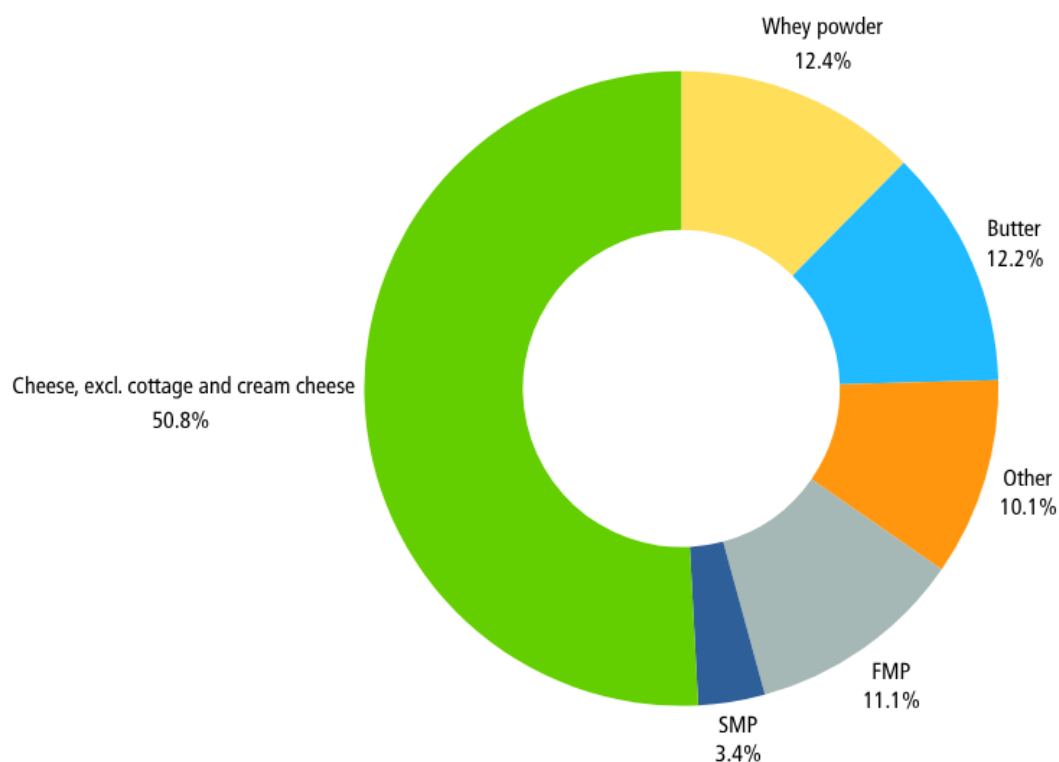


Figure A5.9 Concentrated dairy products – the mass of each product in relation to the total of concentrated dairy products, 2023

Sources: MilkSA (2024); SAMPRO (2024c,d)

Pasteurised liquid milk and UHT processed milk were the major liquid products (Figure A5.10), with hard cheese being the main concentrated product (Figure A5.9) (MilkSA 2024).

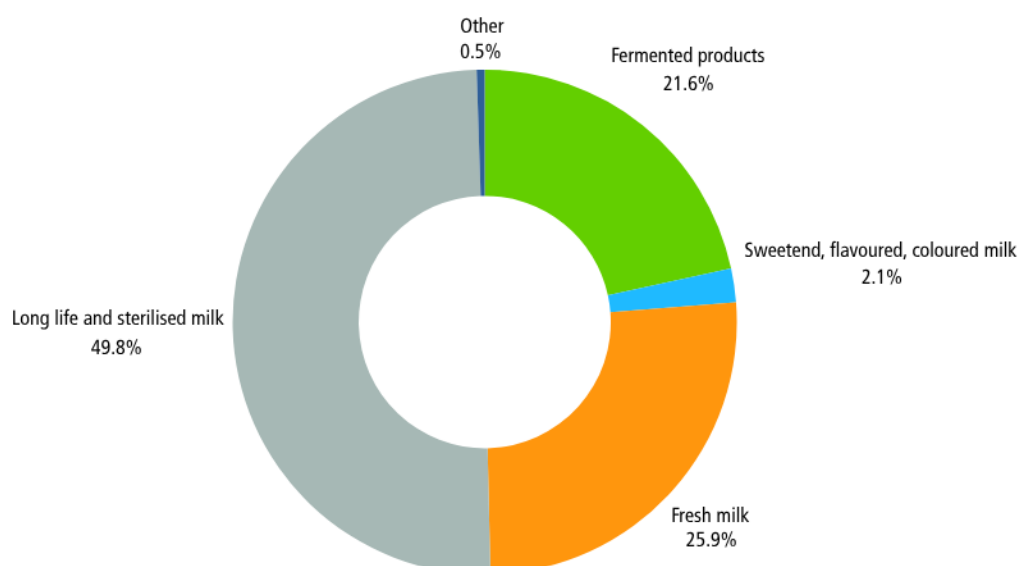


Figure A5.10 Liquid dairy products – the mass of unprocessed milk used in the manufacturing of liquid dairy products, 2022

Sources: MilkSA (2024); SAMPRO (2024cd)

Total dairy product imports and exports in 2023 were 48 000 tonnes of products and 56 000 tonnes, respectively. On a mass basis, imports decreased by 9.4% in 2023, compared with 2022, while exports increased by 7.7% (Figure A5.11). The imports of milk and milk products decreased substantially by 30% to 58 332 tonnes and valued at R2 919 million in 2022, compared to 83 356 tonnes which were valued at R2 709 million in 2021. Contrarily, the exports increased by 1.9% and amounted to 57 259 tonnes with the value of R1 854 million in 2022, from 56 208 tonnes valued at R1 438 million in 2021 (MilkSA 2024).

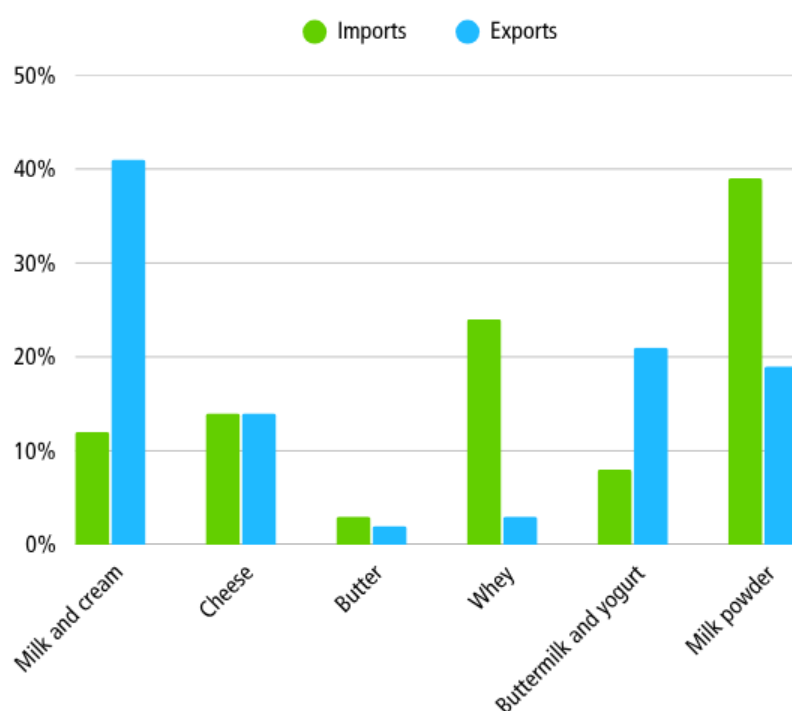


Figure A5.11 Percentage composition of dairy product imports and exports on a mass basis, 2023
Sources: DALRRD (2024b); SAMPRO (2024d)

A5.3 Sheep and goats

Sheep farming is another important sector, contributing to both meat and wool production. The wool industry is particularly significant. South Africa has a large sheep population. Sheep farming is common in regions with extensive pastures, such as the Northern Cape, Eastern Cape, Western Cape, Free State and Mpumalanga provinces with suitable grazing land and favourable climates (Figure A5.12). Sheep farmers are represented by organisations with Dorper Sheep Breeders' Society of South Africa and Merino SA being the most prominent. Certifications for sheep farming include organic and sustainable practices. South Africa exports sheep meat and wool to various international markets (DALRRD 2023d).

Goat farming is important for meat and mohair production, and milk in some regions. It is a growing sector with increasing demand for goat meat. South Africa has a significant goat population, practiced in various regions, often in conjunction with other livestock farming in regions with suitable grazing land and favourable climates. Certifications for goat farming include organic and sustainable practices. South Africa exports goat meat to various international markets (DALRRD 2023d).

In 2022 there were approximately 8 000 commercial sheep farms throughout the country and about 5 800 communal farmers. The estimated number of sheep (Merino, karakul, other woolled sheep and non-wooled sheep) in South Africa is 21.4 million in 2022. Sheep numbers have been declining for the past decade which emanated mainly from predation and stock theft (DALRRD 2023d).

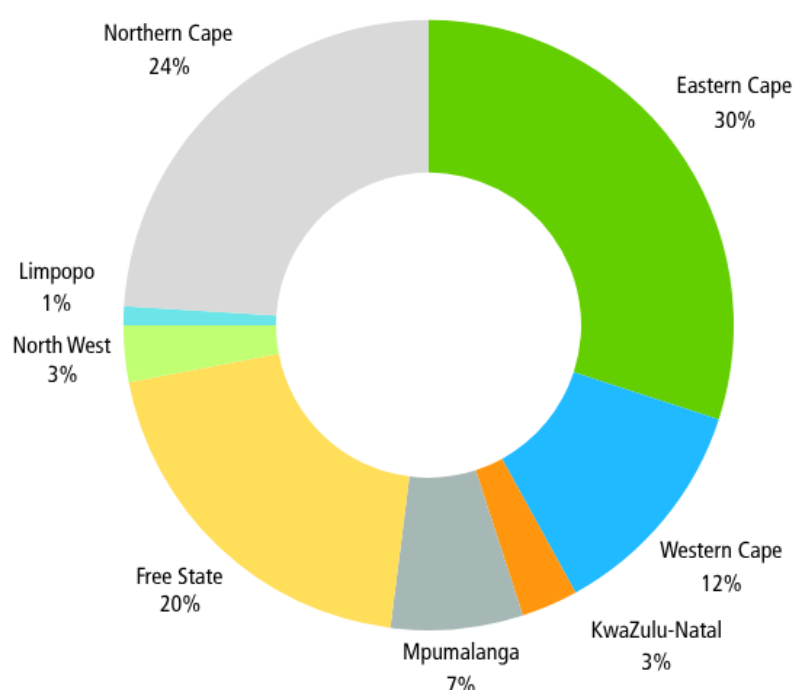


Figure A5.12 Provincial distribution of sheep, 2022
Source: DALRRD (2023d)

The amount of mutton (sheep and goat) consumed is more than what was domestically produced during the 2014 to 2024 (Figure A5.13). The mutton production and consumption show a declining trend from 2014/15 to 2023/24. The decline in production was the result of the flock reduction caused by drought experiences, coupled with continuous stock theft. It may also be attributed to the increasing producer prices, which makes it expensive relative to its alternatives such as beef, chicken and pork. In 2023/24, there was a slight increase in both consumption (Figure A5.14) and production of 1.2% and 0.3%, respectively. The average

producer price of mutton has been fluctuating at an increasing rate in the past decade, with an overall increase of 69.2% over the past decade (DALRRD 2023d, 2024b; RMIS 2025e).

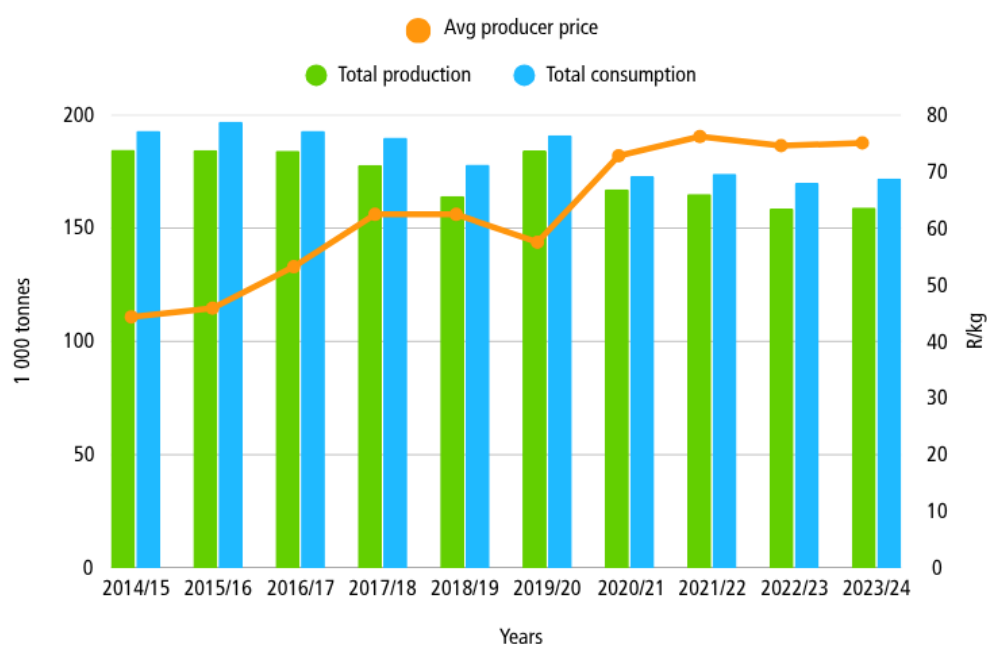


Figure A5.13 Total production and consumption of mutton and average producer price per kg, 2014/15–2023/24
Sources: DALRRD (2023d, 2024b); DALRRD: Directorate Statistics and Economic Analysis (2023); RMIS (2025f)

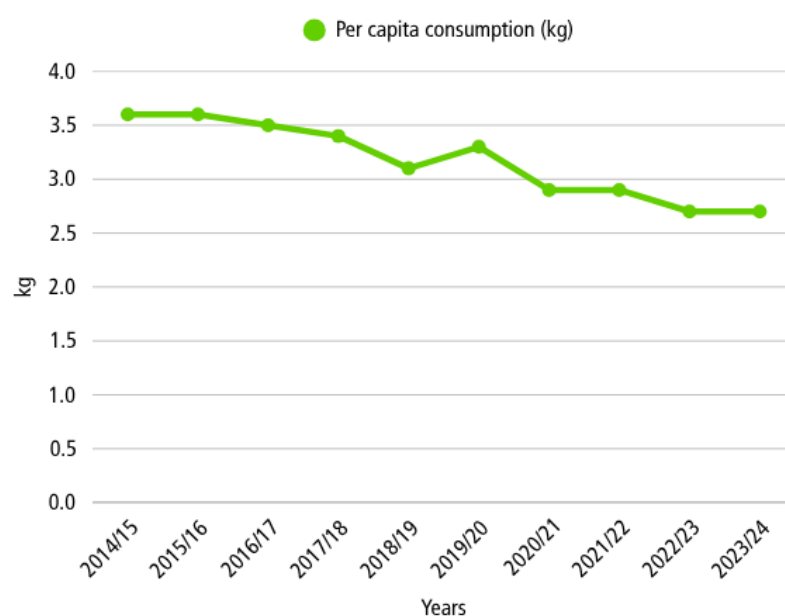


Figure A5.14 Per capita consumption (kg) of mutton, 2014/15–2023/24
Sources: DALRRD (2023d, 2024b); DALRRD: Directorate Statistics and Economic Analysis (2023); RMIS (2025f)

The trends are showing a decline in imports and an increase in exports between 2017 and 2024 (Figure A5.15). Exports of mutton exceeded imports in South Africa for the first time in

2021. Mutton exports increased by 42.3% in 2023 and 84.5% in 2024. Overall, both import quantity and value declined by 68.8% and 146.3% from 2017–2024, respectively (DALRRD 2023d; RMIS 2025d).



Figure A5.15 Mutton export and import value (Rand million) and quantity (thousand tonnes), 2017–2024
Sources: DALRRD (2023d); RMIS (2025d)

Wool and mohair production

The Eastern Cape was the largest wool-producing province during 2022/23 with 16.2 million kg, followed by Free State with 8.6 million kg, Western Cape with 7.9 million kg, Northern Cape with 5.2 million kg and Mpumalanga with 2.0 million kg, while 1.5 million kg were produced in the remaining four provinces combined. The trends of wool sales and the value of wool sales can be seen in Figure A5.16. During 2022/23, the major export destinations for South African wool, in decreasing order of total value and quantities, were as follows: China/Macau/Hong Kong, Czech Republic, Italy, India and Egypt (DALRRD 2023d, 2024b).



Figure A5.16 Wool sales and sales value, 2014/15–2022/23

Sources: DALRRD (2023d, 2024b)

The price of wool is determined by a complex set of variables. From 2014/15 to 2022/23 there was an overall increase of 61% in the average producer price per kg of merino wool as seen in Figure A5.17 (DALRRD 2023d, 2024b).



Figure A5.17 Average producer price per kg in Rand (Merino wool), 2014/15–2022/23

Sources: DALRRD (2023d, 2024b)

Mohair production in South Africa mainly occurs in Eastern Cape and the adjacent part of Western Cape. South Africa produces approximately 53% of the world mohair clip. South Africa's mohair production was stable at 2.4 million kg in 2023 compared to 2.1 million kg in 2019 (Figure A5.18). The trend continues to surge slightly upward in comparison to the two seasons. As seen in Figure A5.19, the average auction price of mohair decreased by 11.75%, from R398.69 in 2022 to R356.94 in 2023 (DALRRD 2023d). In realising the responsibility involved in being the most reliable source of mohair, Mohair South Africa was established to perform functions aimed at the advancement of the entire mohair industry. Through selective breeding and farming techniques, the Angora goat farmer plays a crucial role in promoting the constant availability of quality natural fibres.

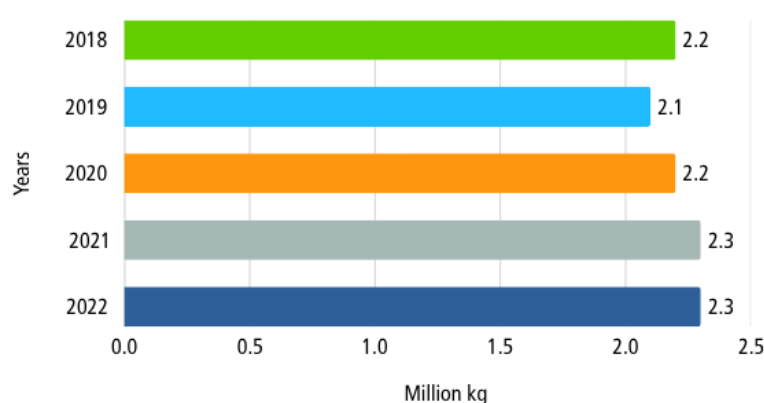


Figure A5.18 Production of mohair (million kg), 2018–2022
Source: DALRRD (2023d)

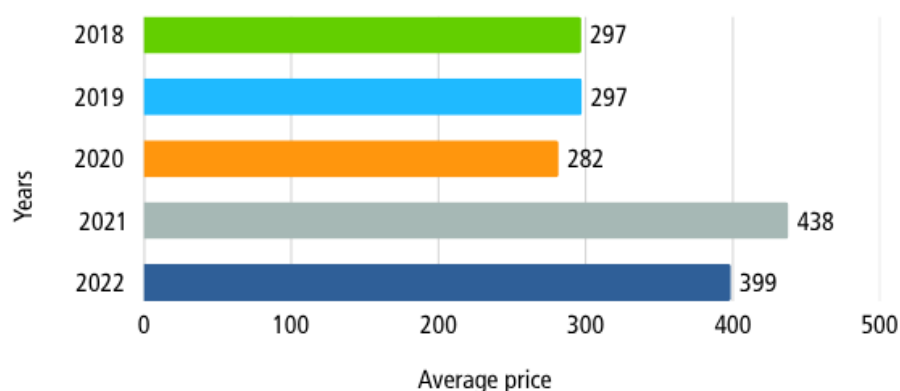


Figure A5.19 Average auction prices of mohair (Rand), 2018–2022
Source: DALRRD (2023d)

Most of the world mohair production is imported to South Africa for further processing, after which it is exported together with locally-produces (including Lesotho) mohair. Italy

became the leader in mohair imports from South Africa in 2020/2021, followed by China and UK. Mohair exports decreased by 15.63% from 2021 to 2022 at an estimated 0.5 million kg (Figure A5.20). It decreased by another 0.1 million kg in 2023. Figure A5.21 shows that the imports remained almost the same between 2021 and 2022 (DALRRD 2023d).



Figure A5.20 Exports of mohair (million kg), 2018_2022
Source: DALRRD (2023d)

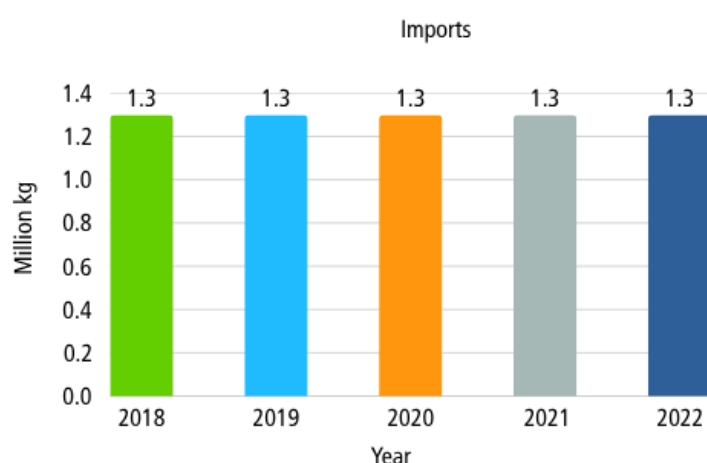


Figure A5.21 Imports of mohair (million kg), 2018–2022
Source: DALRRD (2023d)

A5.4 Poultry

Poultry farming is one of the largest livestock sectors, contributing significantly to meat production. The industry includes broiler chickens and egg production with significant areas dedicated to broiler farms and egg production facilities. Poultry farming is common in regions with suitable facilities and infrastructure. Certifications for poultry farming include organic and

sustainable practices (SAPA 2023). South Africa export poultry meat and eggs to various international markets. Leading poultry organisations in SA include:

5. South African Poultry Association (SAPA)
6. RCL Foods
7. Astral Foods
8. Country Bird Holdings
9. Sovereign Food Investments

Table A5.3 *Provincial distribution of chickens, 2024*

Provincial distribution of chickens in SA			
	Broiler industry	Egg industry	Total
Number of birds			
Eastern Cape	8 325 955	869 265	9 195 220
Western Cape	23 012 751	5 147 796	28 160 547
KwaZulu-Natal	10520 399	3 605 539	14 125 938
Mpumalanga	26 754 409	2 447 836	29 202 245
Gauteng	15 861 498	7 353 020	23 214 518
Free State	13 656 105	4 650 141	18 306 246
North West	33 406 649	3 523 890	36 930 539
Limpopo	4 630 293	2 334 503	6 964 796
Northern Cape	273 000	96 300	369 300
Total	136 441 059	30 028 290	166 469 349

Source: SAPA (2024)

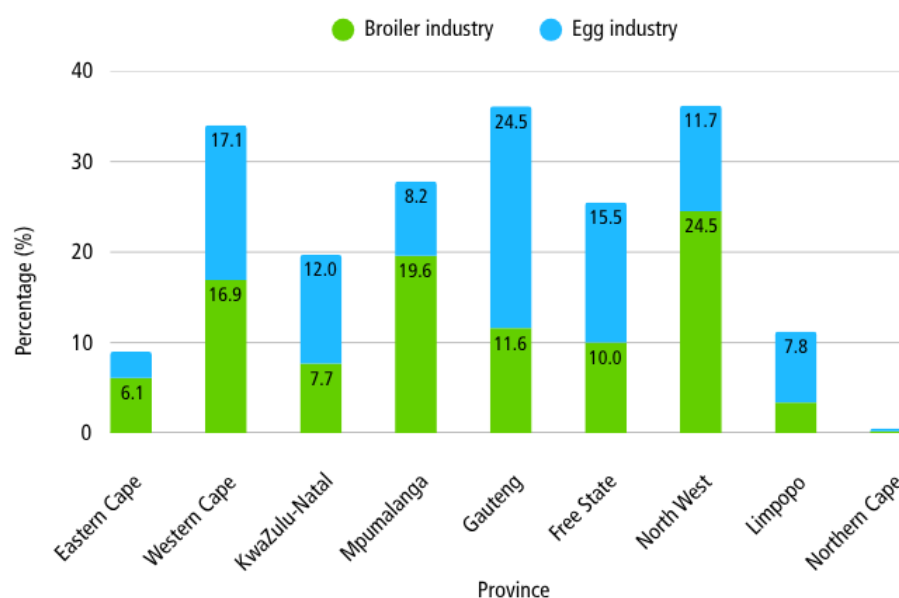


Figure A5.22 *Percentage distribution of the broiler and egg industries, 2024*

Sources: SAPA (2023, 2024)

The provincial distribution of chicken farms (Table A5.3 and Figure A5.22), in terms of the broiler and egg industries: North West has 21% of the farms and 24% of the broiler sector birds. It is closely followed by Mpumalanga. Gauteng has the highest percentages of egg sector farms (24%) and birds (26%) (SAPA 2024). Combined, the gross poultry farm income for 2023 was R79.95 billion, showing a yearly increase of 11.6 % (SAPA 2023).

Broiler industry

In 2021/22, this sector generated R54.1 billion in gross value, about 13.4% of the total gross value of agricultural products. The gross value of primary agricultural production from poultry meat for 2023, as recorded by DALRRD, was R65.77 billion, an 11.5 % increase from 2022. In comparison to other livestock products, broiler accounts for 32% of all animal products in South Africa in Rand terms. South Africa remains the major broiler producer in Southern Africa accounting for 75% of total broiler production in the region. Broiler production dominates the agricultural sector and remains the cheapest protein supplier relative to other animal proteins followed by beef (SAPA 2023; DALRRD 2023b).

Egg industry

With a gross turnover of R14.18 billion at producer level, eggs retain their position as the fourth largest animal product sector in agriculture in South Africa, after poultry meat (R65.77 billion), beef (R45.54 billion) and milk (R26.91 billion). Turnover rose by 12.5 % compared to 2022, after an annual increase of 18.7% the previous year. Eggs' share of the gross value of animal products was 7.6% and 3.2% of all agricultural production, up from 7.1% and 3.0%, respectively, the previous year. The total value of eggs at retail level was estimated to be R23.05 billion for 2023. About 612 million dozen eggs were sold during the year through various channels (SAPA 2023; DALRRD 2023c).

Production and consumption of chicken in SA

Broiler meat production has shown an increasing trend of 9% between 2014/15 and 2023/24 (Figure A5.23). Broiler meat production has shown a slight decrease of 1.7% from 2022/23 to 2023/24. Broiler meat consumption has shown an increasing trend of 5% between 2014/15 and 2023/24. South Africa consumes more broiler meat than what is produced locally. During 2023/24, South Africa produced a total of 1.8 million tonnes of broiler, while its consumption was at 2.1 million tonnes in the same year (SAPA 2023; DALRRD 2023b).

Egg production the past five years has shown a decreasing trend of 18.6% in the number of cases produced annually per week (Figure A5.23). The average number of cases of eggs produced per week for 2023 was 391 400, a decrease of 70 800 cases (15.3% decrease) per week. (On average there is 18 500 eggs per case, with an average weight of 60g per egg.) Total egg production in 2023 amounted to 20.39 million cases, or 611.8 million dozen eggs; a decrease of 15.3% compared to 2022 because of epidemics (SAPA 2023; DALRRD 2023c).

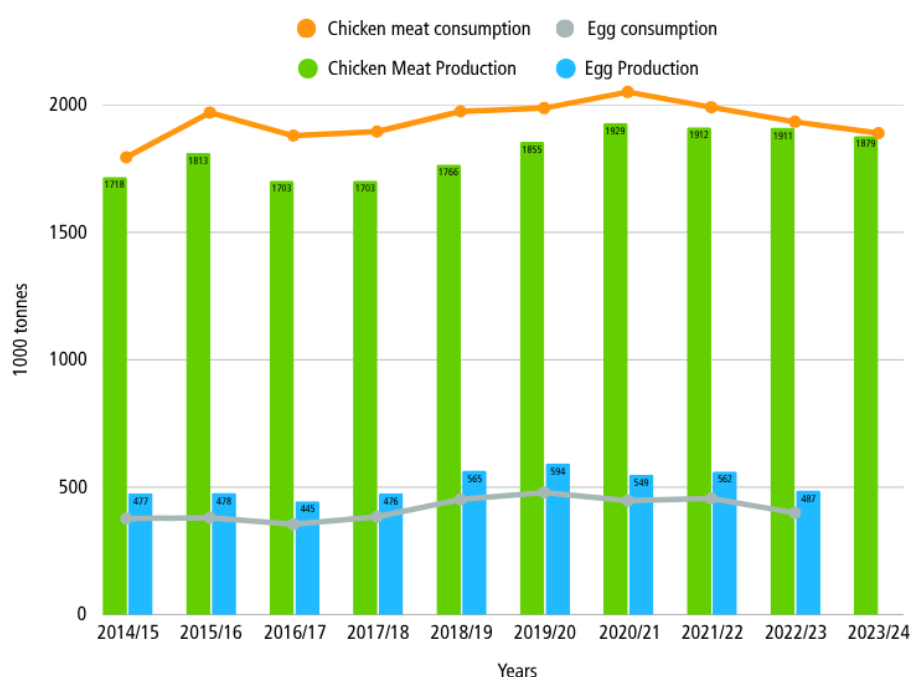


Figure A5.23 Chicken meat and egg production and consumption (thousand tonnes), 2014/15–2023/24

Sources: SAPA (2023); DALRRD (2023bc); DALRRD: Directorate Statistics and Economic Analysis (2023)

As seen in Figure A5.24, the per capita consumption of broiler meat in South Africa has shown a decrease of 1.19 kg per person in 2023/24, which marks an approximately 3.4% decrease. The per capita consumption in 2022/23 was 148.6 eggs or 9.08 kg compared to 146.4 eggs or 8.95 kg in 2021 (SAPA 2023; DALRRD: Directorate Statistics and Economic Analysis 2023).

In 2023, per capita consumption decreased from 148.2 eggs (9.06 kg) the previous year to 123 eggs (7.52 kg). The per capita consumption of eggs decreased by 17%, while the population increased by 1.1% to 61.3 million (SAPA 2023; DALRRD: Directorate Statistics and Economic Analysis 2023).

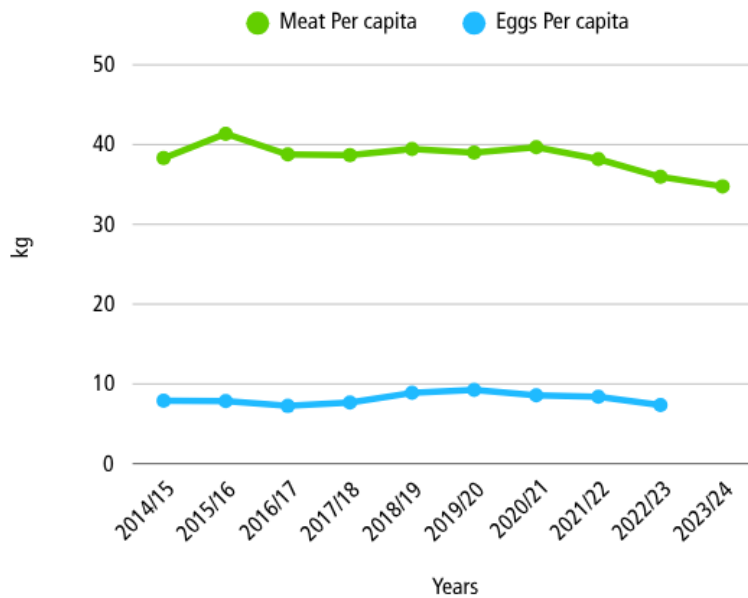


Figure A5.24 Chicken meat and egg consumption per capita (kg), 2014/15–2023/24

Sources: SAPA (2023); DALRRD (2023bc); DALRRD: Directorate Statistics and Economic Analysis (2023)

The producer prices show an increasing trend for the past decade (Figure A5.25). The average broiler producer price for this period was R27/kg and the average egg producer price R13.56 per dozen (ungraded eggs). The broiler producer price in 2023/24 was R29.36/kg, which was R3.18 higher than the previous year (SAPA 2023; DALRDD 2023b).

The average price received by egg producers during 2024 was 29.8% more than the average price received during the same period of 2023. The average egg producer price in 2023/24 was R19.83 per dozen for ungraded eggs (a 31.3% increase), and graded eggs averaged on R23.62 per dozen (a 29.1% increase) (SAPA 2023; DALRDD 2023c).

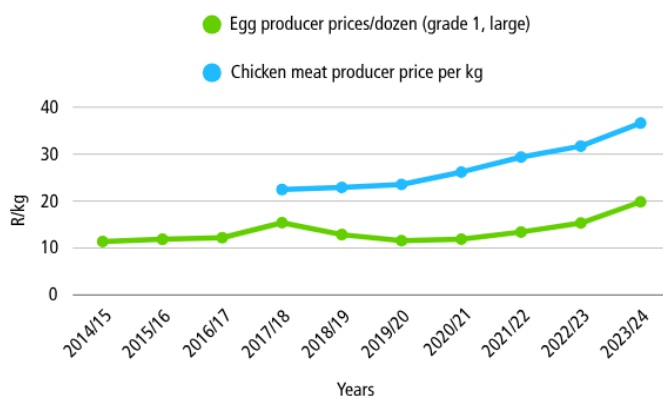


Figure A5.25 Egg producer prices/dozen and chicken meat producer price per kg in Rand, 2014/15–2023/24

Sources: SAPA (2023); DALRRD (2023bc); DALRRD: Directorate Statistics and Economic Analysis (2023)

On a rand-per-kg basis, eggs were the most affordable animal protein source in 2023 at R31.30/kg, followed by chicken (R31.70/kg) and pork (R33.96/kg) as shown in Figure A5.26 (SAPA 2023).

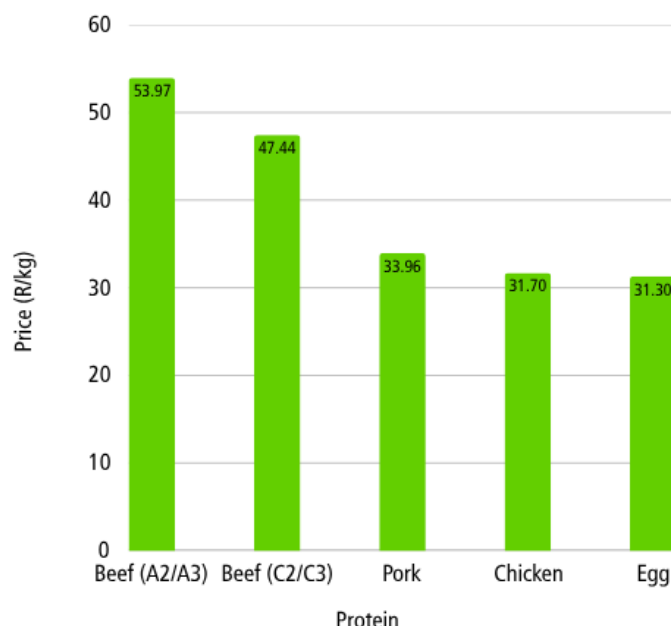


Figure A5.26 Comparison of producer prices of animal proteins (Rand), 2023
Source: SAPA (2023)

A total of 48 534 tonnes of poultry products (chicken, turkey, ducks, geese and guinea fowl) was exported at a value of R 1.384 billion during 2023. This was a decrease of 6% on 2022 tonnages (Figure A5.27). Chicken exports accounted for 96.4% of total poultry exports in 2023 (46 789t), and 94.3% of the rand value (R1.305 billion) of total poultry exports. Chicken exports dropped by 6.6% in 2023 (SAPA 2023; DALRRD 2024b).

South Africa's annual chicken imports for 2023 totalled 399 702 tonnes, an 11.0% increase on 2022 levels. Chicken imports in 2023 were 13.4% lower than the 5-year average (2018 to 2022). The value of imports for 2023 increased by R63.2 million (1.5% increase) from the 2022 value, to R4.248 billion. Chicken imports represent 96.3% of the total poultry products imported. Chicken imports contributed 18.2% of chicken consumption in South Africa in 2023 (SAPA 2023; DALRRD 2024b).

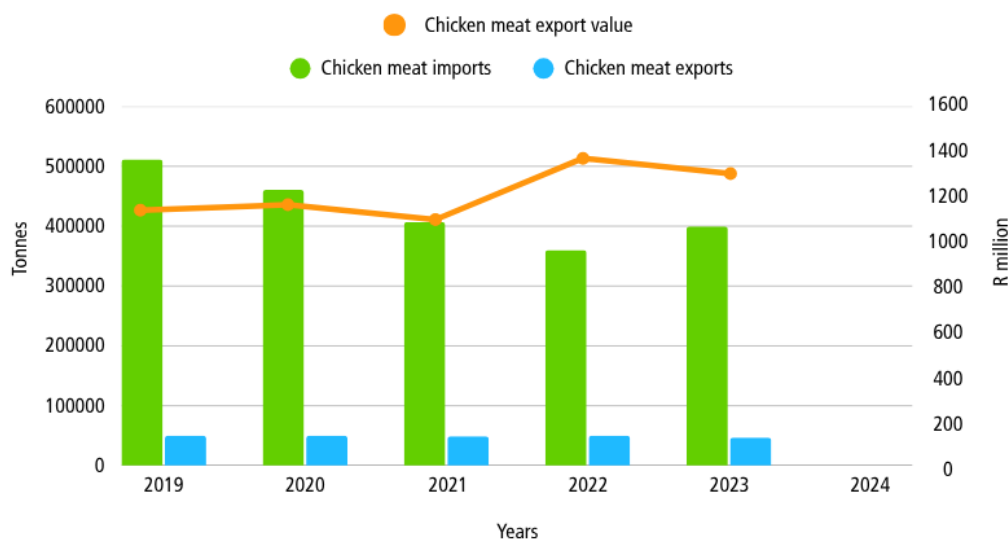


Figure A5.27 Chicken meat imports and exports quantities (tonnes) and value (R millions), 2019–2023
 Sources: SAPA (2023); DALRRD (2023b); DALRRD: Directorate Statistics and Economic Analysis (2023)

Egg exports for 2023 totalled 5 128 tonnes. Egg exports had recovered somewhat in 2022, following the 2021 avian influenza epidemic, but exports have dropped by 42.3% in 2023 because of the latest HPAI-related culls. The total value of all egg exports was R265.6 million, a 27.3% decrease from 2022. The bulk of the egg products exported were liquid (4.92 tonnes; 76.3% of total egg products). Liquid egg products comprised 1.44 tonnes raw egg pulp, 3.2 tonnes liquid egg yolks and 0.7 tonnes of egg albumins (DALRRD 2023c; SAPA 2023).

Total imports of chicken eggs, including fertile eggs, shell eggs and egg products (liquid and dried), increased from 752 tonnes in 2022 to 3 854 tonnes in 2023 (413% increase). Imports had a value of R420.2 million, a 274% increase (Figure A5.28). The egg industry was forced to act following the culling of layer breeder flocks infected with HPAI. Fertile eggs accounted for 71.5% (2 757 tonnes) of total egg imports in 2023 (DALRRD 2023c; SAPA 2023).

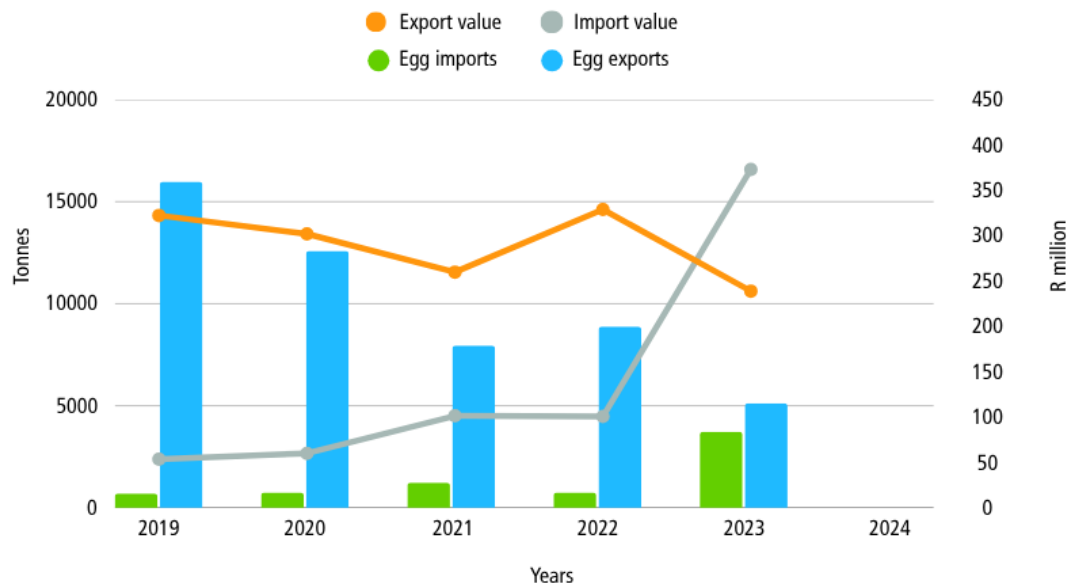


Figure A5.28 Egg imports and exports quantities (tonnes) and value (R millions), 2019–2023
 Sources: SAPA (2023); DALRRD (2023c); DALRRD: Directorate Statistics and Economic Analysis (2023)

A5.5 Pigs

Pig farming is a major sector, contributing to pork production. Pork is one of the smallest industries in terms of overall South African agricultural sector. South Africa has a substantial pig population and is concentrated in regions with suitable facilities and infrastructure. The South African Pork Producers' Organisation (SAPPO) is the official mouthpiece for pork producers in South Africa. The organisation is primarily concerned with administration, liaison with government, the promotion of pork and pork products and matters of national interest such as health and research. Certifications for pig farming include organic and sustainable practices. South Africa exports pork to various international markets (DALRRD 2022).

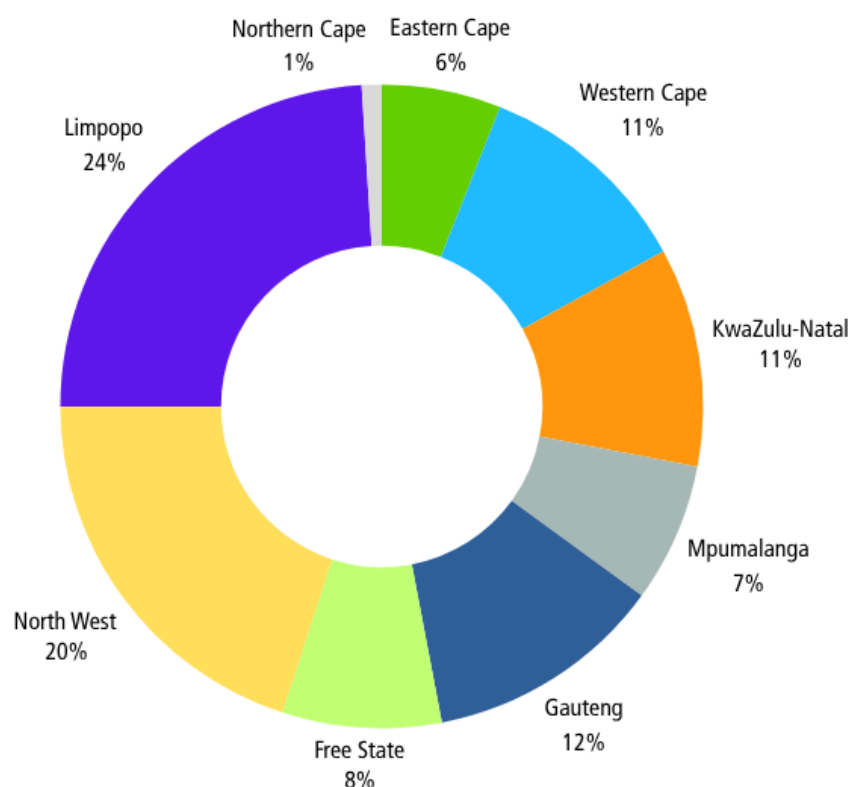


Figure A5.29 Provincial distribution of pigs, 2022
Source: DALRRD (2022)

Pigs are found in high numbers in Limpopo, North West, Gauteng and Western Cape (Figure A5.29). There are approximately 400 commercial pork producers and 19 stud breeders in South Africa. It is estimated that pig numbers declined by 0.45%, from 1 321 million to 1 315 million between August 2023 and August 2024 (Figure A5.30). The average gross value of pigs slaughtered over the past 10 years amounted to R5.4 billion per annum (DALRRD 2022).

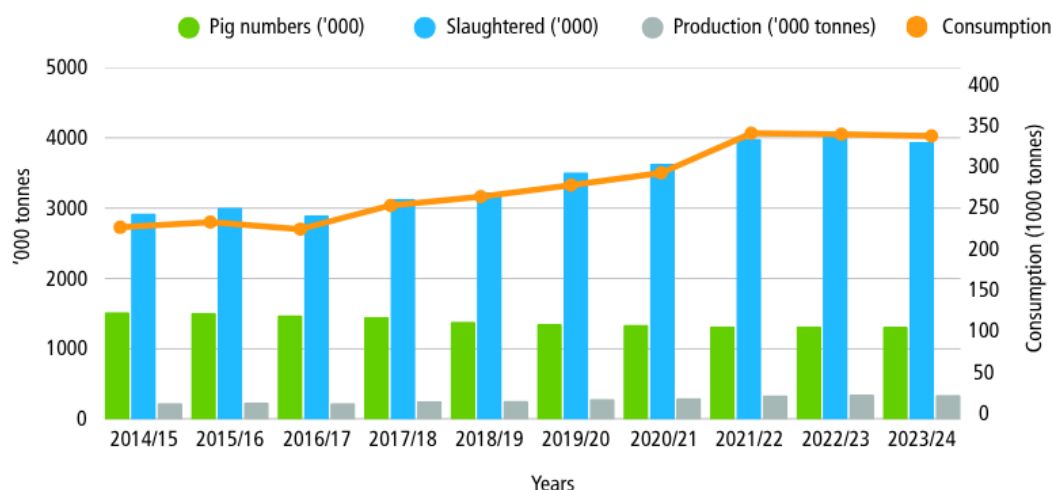


Figure A5.30 Pig numbers, numbers slaughtered and production and consumption (thousand tonnes) of pork, 2014/15–2023/24

Sources: DALRRD (2022, 2024b); DALRRD: Directorate Statistics and Economic Analysis (2023)

During the past decade, approximately 30.6 million pigs were slaughtered, yielding more than 2.5 million tonnes of pork meat. On average, 3 million pigs were slaughtered and produced an average of 250 900 tonnes per year for 2014/15 to 2023/24. Pork meat production and slaughtering has shown an increasing trend of 48.8% and 34.8%, respectively, between 2014/15 to 2023/24. The per capita consumption has an increasing trend from 2014/15 to 2023/24. Pork consumption has shown an increasing trend of 41.3% over the past decade (DALRRD 2022, 2024b; DALRRD: Directorate Statistics and Economic Analysis 2023).

The average producer price of pork has shown an overall increasing trend for the period between 2014/15 and 2023/24 as seen in Figure A5.31. Pork producer prices in 2024 were on average R24.4 per kg (an 8.8% decrease) from the previous year (DALRRD 2022; DALRRD: Directorate Statistics and Economic Analysis 2023).

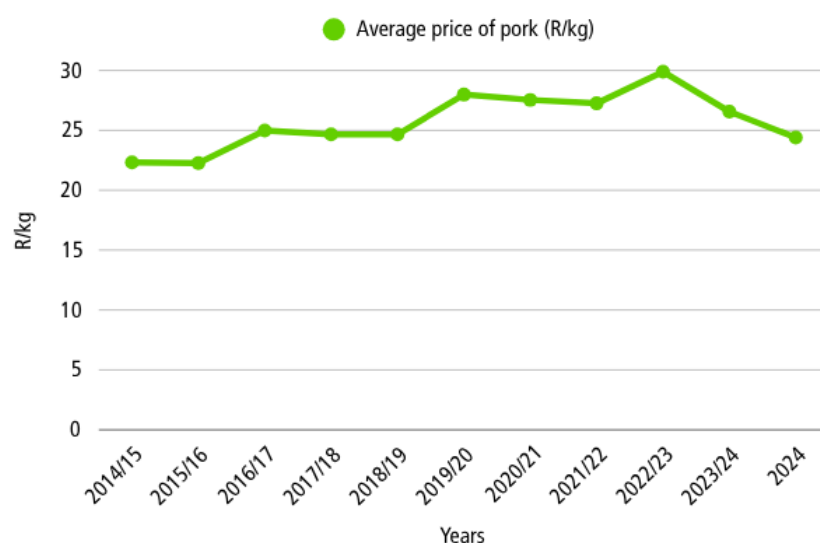


Figure A5.31 Average producer price of pork (R/kg), 2014/15–2024

Sources: DALRRD (2022, 2024b); DALRRD: Directorate Statistics and Economic Analysis (2023)

Imports of pork amounted to 19 608 tonnes, an increase of 8.4% from the 18 081 tonnes imported during 2023/24 and 6.0% lower than the five-year average of 20 869 tonnes up to 2023/24 (Figure A5.32). On average, South Africa exports over 8 662 tonnes per annum in past decade. Exports value and quantity of pork was slightly fluctuating at an increasing trend from 2012 to 2022 (DALRRD 2022, 2024b).

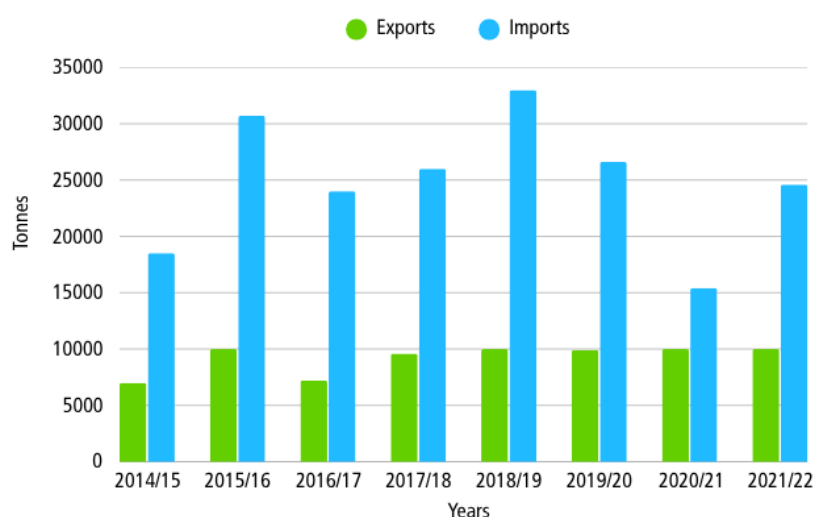


Figure A5.32 Pork exports and imports quantities in South Africa, 2014/15–2021/22

Sources: DALRRD (2022, 2024b); DALRRD: Directorate Statistics and Economic Analysis (2023)

ANNEXURE 6: Details of horticulture sub-branches

A6.1 Viticulture

A6.1.1 Table grapes: production, area under production and location

Table grapes are one of the most significant deciduous fruits grown in South Africa, when considering their foreign exchange earnings, employment creation and linkage with support institutions (DALRRD 2020). The grapes grown for consumption usually have lower sugar content than grapes grown for wine and are usually more flavourful.

The gross value of production of table grapes in 2023 was R11.8 billion, up from R4.2 billion in 2009, representing a 152% increase over the 15 years (DALRRD 2024a). The peak was in 2018, when gross value was R12.3 billion and this was due to an increase in exports.

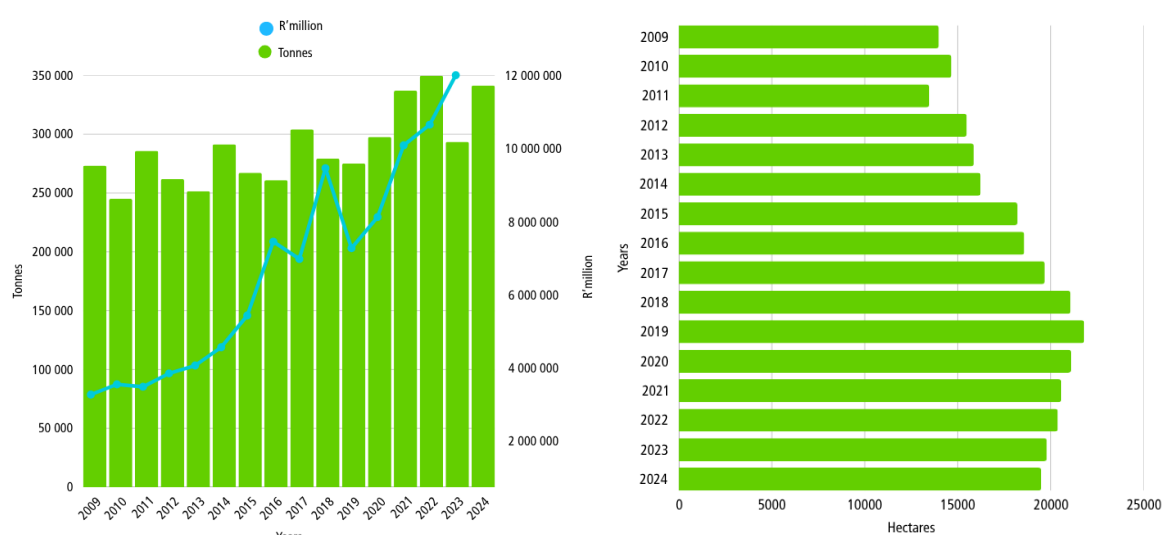


Figure A6.1 Tonnage of table grapes produced relative to gross value of production (R' million) and the change in total hectares planted under table grape vineyards, 2009–2024

Source: SATI reports from 2011, 2012, 2013–2014, 2014–15, 2018, 2020 and 2024

Total production of table grapes has increased from 273 372 tonnes in 2009 to 341 306 tonnes in 2024, showing a 25% increase over this time (SATI 2024). Area planted to table grape vines has increased almost 40% in the past 15 years, increasing from 13 982 hectares in 2009, to 19 488 hectares in 2024. This relatively steep increase in area planted has been the main driver of production growth. Despite South Africa having unique resources conducive to the production of table grapes, the prolonged droughts from 2015–2016 and 2018–2020, impacted the yields produced (Van der Merwe et al. 2024). However, farmers are responding to changing consumer preferences, shown by the area planted to new varieties, such as Sweet Globe and Autumn Crisp.

There are five table grape growing areas, with the Hex River being the largest (over 6 100 hectares or 32% of total area), followed closely by the Orange River (over 5 700ha or 29% of total area) and the Berg River (over 4 500ha or 23% of total area).

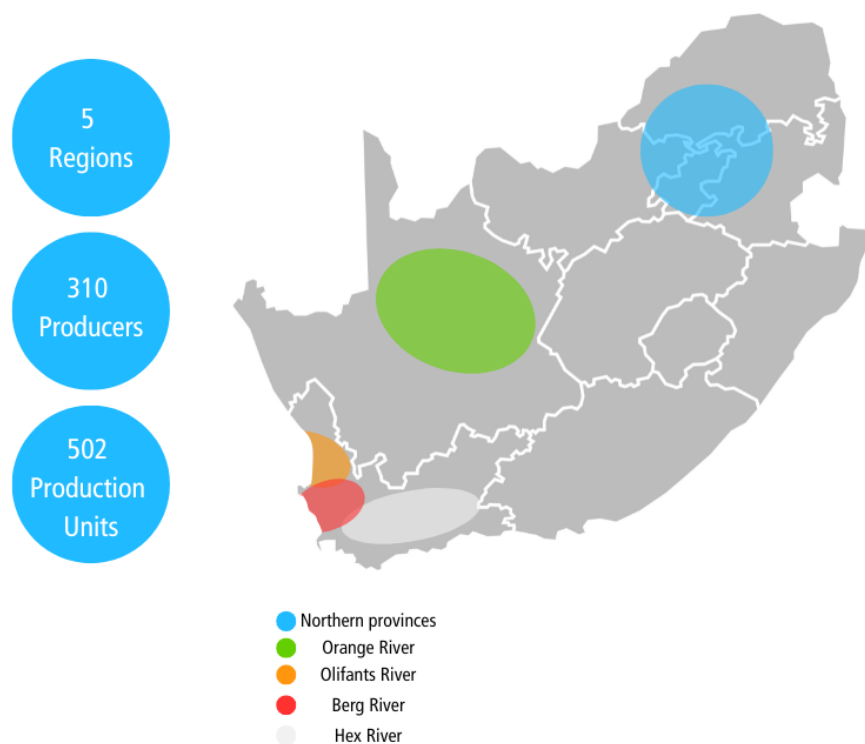


Figure A6.2 Location of table grape production showing the five main regions: Northern Province, Orange River, Olifants River, Berg River and Hex River

Source: SATI (2024)

In 2023, the table grape sector employed 14 511 permanent workers and 84 000 seasonal workers, compared to 14 652 permanent and 52 433 seasonal workers in 2009. The number of producers has decreased from 466 to 310 over this same 15-year period, indicating an increased market concentration in this sector.

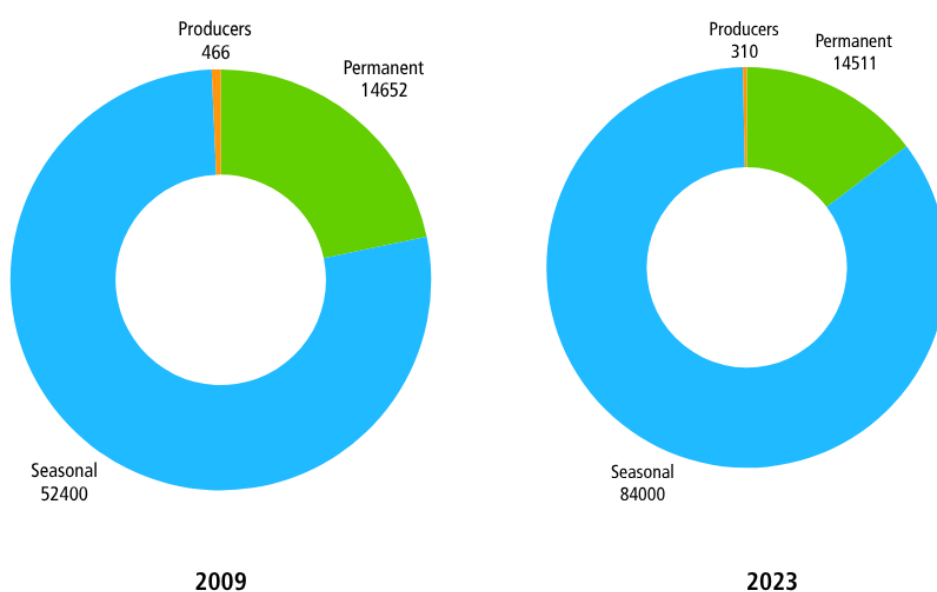


Figure A6.3 Comparison of workforce in the table grape industry, 2009 and 2023

Source: SATI (2024)

Given the distribution of growing areas, it is not surprising that the Hex River has the highest number of permanent employees, providing 5 085 jobs in 2023, which makes up 35% of total permanent employment in the table grape sector.

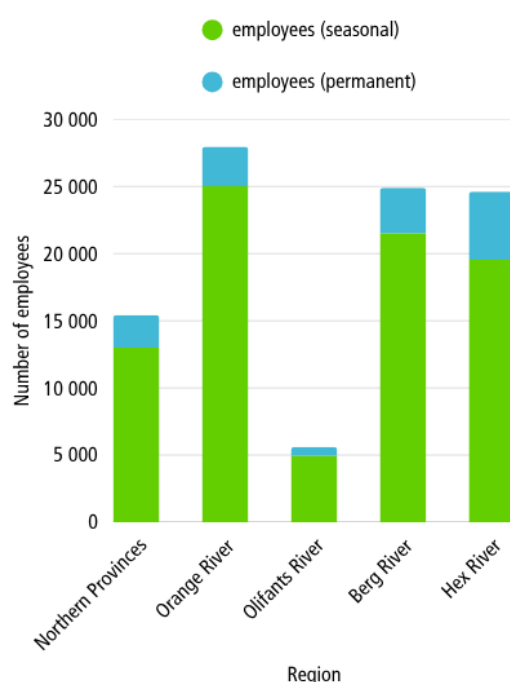


Figure A6.4 *Distribution of employment across the five regions of table grape production*
Source: SATI (2024)

A6.1.2 Wine grapes: production, area under production and location

The South African wine industry encompasses more than just wine, and includes wine (still, fortified and sparkling), wine for brandy, distilling wine, brandy and other spirits distilled from distilling wine, in addition to grape juice and grape juice concentrate used in wine and non-alcoholic products (SAWIS 2023).

The production of wine grapes has shown a 21% decline in production since 2010, decreasing from 1.26 million tonnes in 2010, to 1.18 million tonnes in 2023. This coincides with a 12% decrease in area planted to wine grape vines which shrunk from 99 689 hectares in 2010 to 87 848 hectares in 2023 (SAWIS 2023).

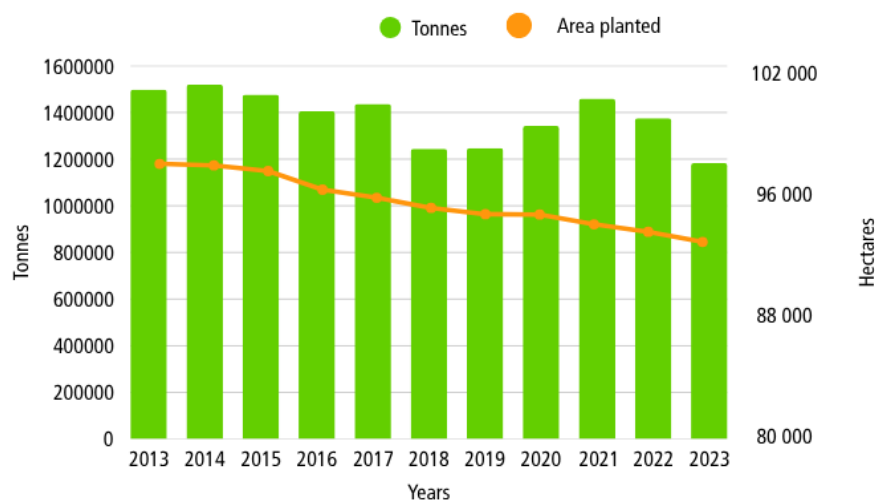


Figure A6.5 Trends in tonnage of wine grapes produced, 2013–2023 and how this corresponds to the decline in total area (hectares) planted to wine grape vineyards
Source: SAWIS (2023)

Reasons for the decline in area under production are the increased costs of labour, mechanisation and direct costs, such as herbicides, pesticides and fertiliser. These cash constraints result in producers delaying re-planting and expanding areas. Producers are enhancing cultivation methods and technology for better yields or switching to more profitable ventures, like higher value crops or tree-nut production (Moobi 2024a).

In 2023, 775.5 million litres of wine was produced, with 66% being white wine. This corresponds to the area planted to white wine grapes, which amounts to 55% of the total area planted. The total tonnage of wine grapes produced is used for a variety of purposes with 83% being used for wine, 12.5% for distilling wine and smaller proportions for brandy and grape juice concentrate.

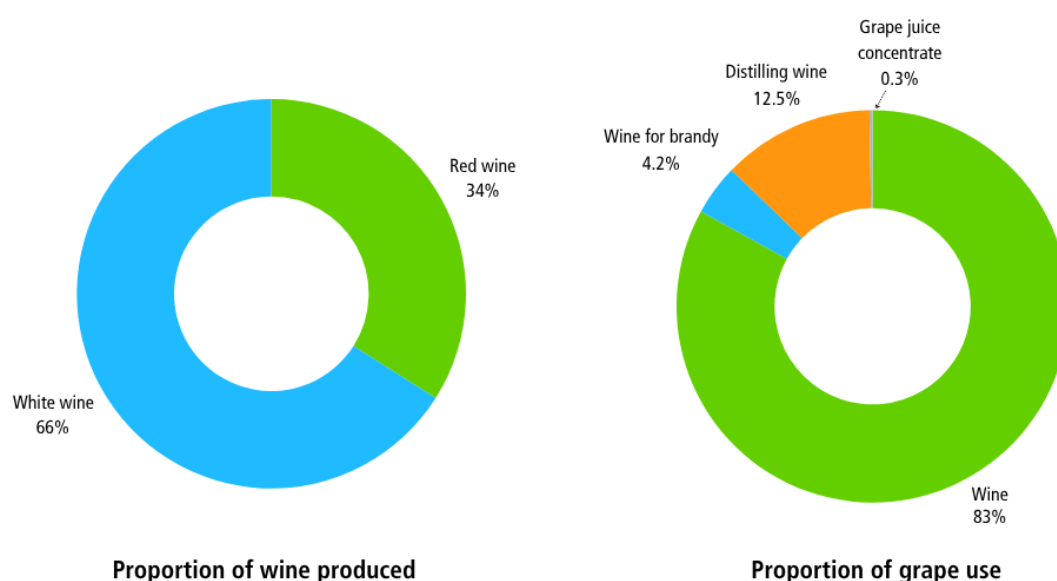


Figure A6.6 Share of wine produced and the different uses of wine grapes
Source: SAWIS (2023)

The wine grape industry employs around 86 000 employees, which includes both on the farm and in cellars, and over 270 000 employees in the entire value chain (WOSA 2024). There are 2 350 primary wine grape producers and 522 wineries. Many of these wineries are small, crushing between 1 and 500 tonnes of grapes. In 2010, there were 3 596 wine grape producers, showing a 35% decline since 2010 (Moobi 2024a).

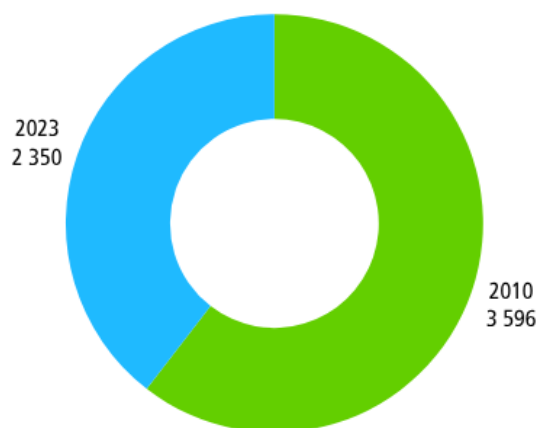


Figure A6.7 The change in number of wine grape producers, 2010–2023
Source: Moobi (2024a)

Wine grape production predominantly takes place in the Western Cape given its conducive climate. The main areas of production are Paarl, Robertson, Bredekloof and Swartland. The areas seeing the largest change in area planted include the Northern Cape, which has decreased by 49% and the Klein Karoo which has decreased by 24% since 2013. The Cape South Coast, Bredekloof and Worcester have seen the least change in area over this period.

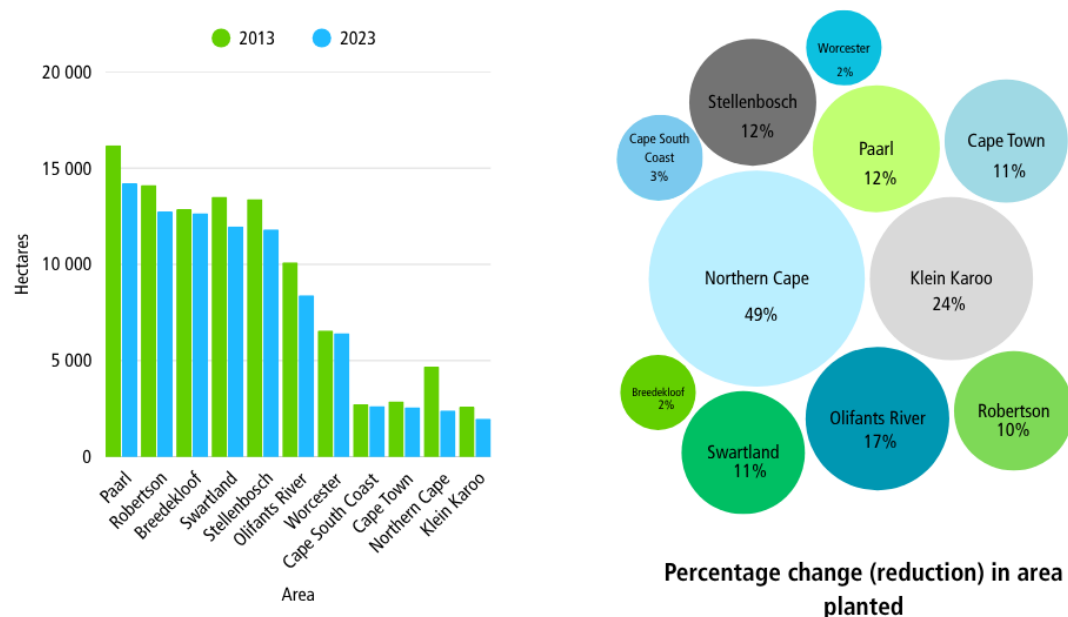


Figure A6.8 Change in area planted under wine grapes according to main geographic locations
Source: SAWIS (2023)

A6.1.3 Table grape markets, exports and certification requirements

The table grape industry is primarily export-driven, exporting more than two-thirds of grapes destined for export. Table grapes sold in the export markets achieve a higher unit price and therefore the industry is oriented towards understanding the rules and maximising opportunity of the export market (DALRRD 2020). South Africa producers are a significant global player, with South Africa ranking as the fourth largest exporter of table grapes in the world, after Chile, Peru and China (Van der Merwe et al. 2024). The primary importers are in the northern hemisphere (EU 50% and UK 20%), where these grapes are supplied during their winter and spring seasons, giving South Africa the counter-seasonal advantage. South Africa is considered the northern hemisphere's most reliable and oldest supplier of table grapes, with the first grapes shipped over a century ago (DALRRD 2020).

South Africa has had a long trading relationship with Europe, receiving preferential market access, enabling table grapes to be exported at a 0% tariff (Van der Merwe et al. 2024). The Netherlands is the leading export destination for South African table grapes, making up, on average, 57% of EU's share of the exports and 43% of total exports from 2010–2019 (DALRRD 2020).

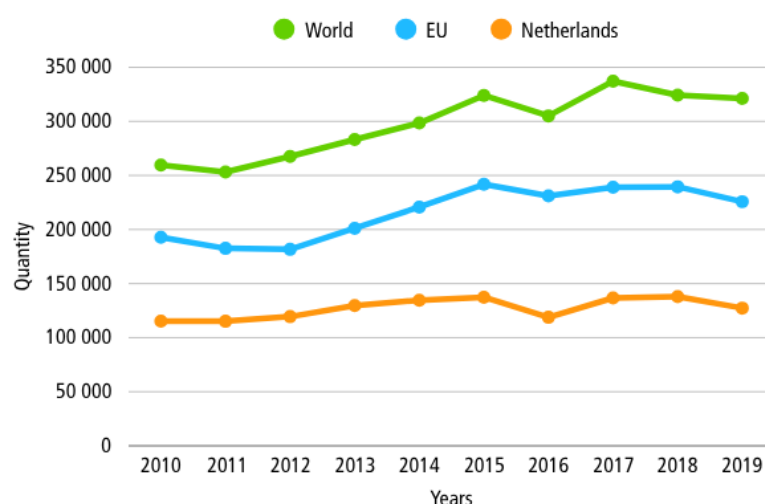


Figure A6.9 Volume of table grape exports, 2010–2019

Source: SATI (2024)

However, despite the lack of tariff barriers to trade with the EU, there are significant non-tariff barriers which include legal export requirements as well as environmental and social non-legal requirements and private certification standards (DALRRD 2020). Furthermore, deterioration of infrastructure and port operations affect the quality of exports and therefore the policy environment needs to support the industry, as this impacts South Africa's table grape competitiveness (Van der Merwe et al. 2024).

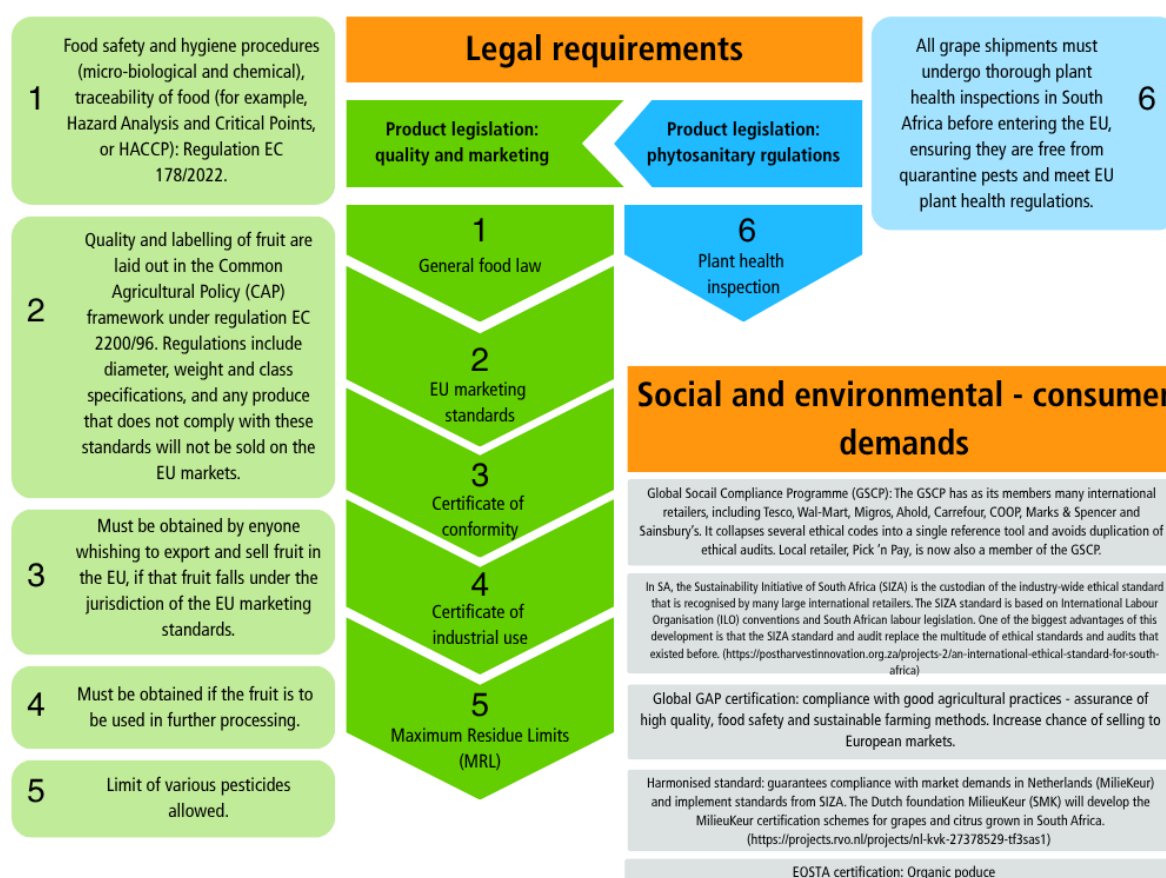


Figure A6.10 Non-tariff barriers in place including legal requirements and social and environmental standards
Source: Adapted from text in DALRRD (2020)

The European Green Deal and the Farm to Fork Strategy (which is currently undergoing revision) aim to achieve several significant targets by 2030. These include reducing the use and risk of pesticides by 50%, decreasing the utilisation of hazardous pesticides by 50%, and lowering maximum residue levels (MRLs) for certain chemicals. A list of chemicals that are banned or severely restricted in the EU has also been provided. South African producers will be subject to the same production and input constraints as their European counterparts, in accordance with the mirror clause (Cloete et al. 2024).

For the table grape industry, the most concerning active ingredient that will come under threat is *dimethomorph*. Dimethomorph is a very effective control for downy mildew, and if the MRL changes to 0.01–0.05 mg/kg, as expected, it will no longer be available to producers whose table grapes are marketed in the EU. While there are alternative ingredients, research shows that it is likely the quality of the grapes will be negatively affected by this ban (Cloete et al. 2024).

The export market is critical to the table grape industry and producers are heavily reliant on generating cartons for the export market. The high exposure to the EU market, combined with the risk of a decrease in quality due to downy mildew, is of major concern (Cloete et al. 2024). Scenario analysis reveals diminished economic sustainability especially for marginal vineyards with consequences resulting in vineyards being uprooted, and negative knock-on effects in the rest of the value chain. A projected loss of 2 440 hectares of vineyard (12.3%) by 2033 is estimated accompanied by a loss of 7 320 full-time equivalent jobs at farm-level (Cloete et al. 2024).

A6.1.4 Wine grape markets, exports and certification requirements

The wine industry is predominantly focused on the domestic market; however, around 40% of production is exported. In 2024, the wine export market was valued at R10.3 billion, with the UK, Germany and the Netherlands being the top three markets based on value (WOSA 2024).

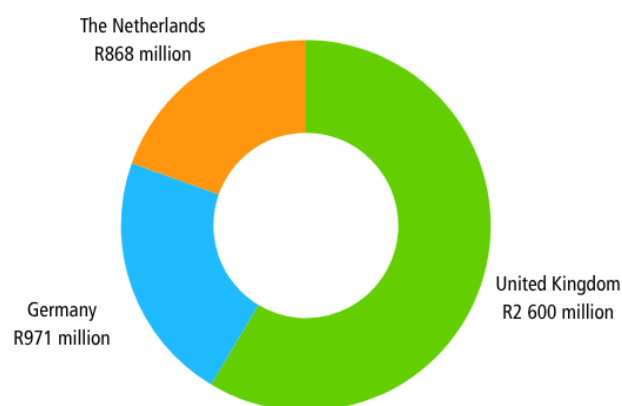


Figure A6.11 Top three markets by value: wine exported, 2024
Source: SAWIS (2024)

South Africa exported 306.2 million litres of wine in 2024, with the EU and UK making up most exports (WOSA 2024). The SADC EU Economic Partnership Agreement continues to offer significant advantages to South Africa with reduced tariffs and improved access to European market. Exports to the Netherlands increased by 18% from 2023 to 2024, exporting 14.5 million litres of wine in 2024 (predominantly packaged rather than bulk) (Moobi 2024a).

South Africa also benefits from a duty-free access into the Southern African Customs Union and there has been remarkable growth in the portion of South African wine exported to other African countries. South Africa is ranked sixth in terms of wine exported, eighth in terms of wine produced and fourteenth in terms of area under grape vines (SAWIS 2024).

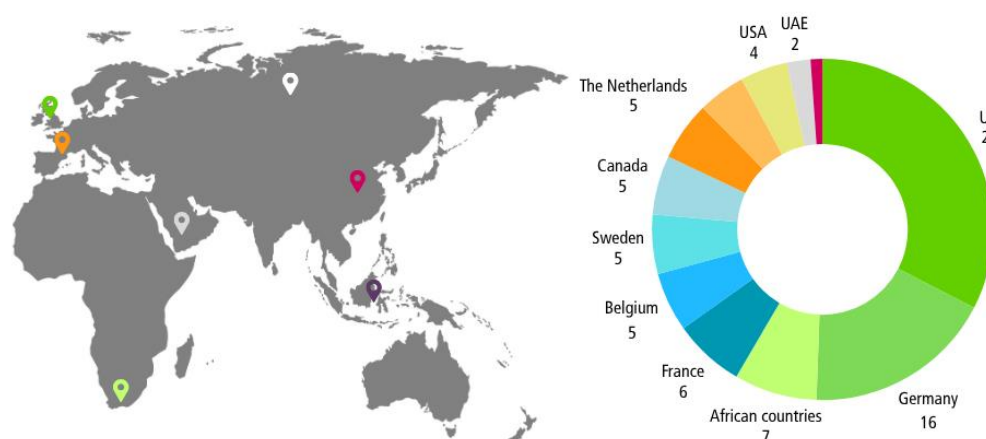


Figure A6.12 Destination of South African wine exports
Source: SAWIS (2024)

For export, South African wines must be certified by the Wine Certification Authority (WCA) and have an export licence. The WCA administers a joint seal which includes the Wine of Origin (A certification seal that verifies the origin, vintage, and grape variety) as well as the Integrated Production of Wine (a certification scheme for sustainable, environmentally friendly wine production) (SAWIS website).

A6.1.5 Role-players and institutions

Figure A6.13 shows the key role-players within the viticulture sector and further information is captured in Annexure 7.



Figure A6.13 Role-players within viticulture

Sources: The South African Table Grape Industry (SATI) (<https://www.satgi.co.za/>); Fruit SA (<https://fruitsa.co.za/>); HortGro (<https://www.hortgro.co.za/>); Wines of South Africa (WOSA) (<https://www.wosa.co.za/home/>); SA Wine Industry Information and Systems (<https://www.sawis.co.za/>); VinPro (<https://vinpro.co.za/>); South Africa Wine (<https://sawine.co.za/>); NAMC (<https://www.namc.co.za/>); South African Wine Industry Transformation Unit NPC (<https://witu.co.za/>)

A6.2 Fruit and Nuts

A6.2.1 Citrus fruit

Economics, scale of production and location

In 2023, a total of 3.6 million tonnes of citrus was produced of which 49% comprised oranges, 21% consisted of lemons and limes, and 15% was soft citrus. Citrus has seen an average growth rate of 11% of tonnage produced over the past five years. Since 2019, lemon production has increased by 65%, soft citrus by 99% and naartjies by 118% (DALRRD 2024a).

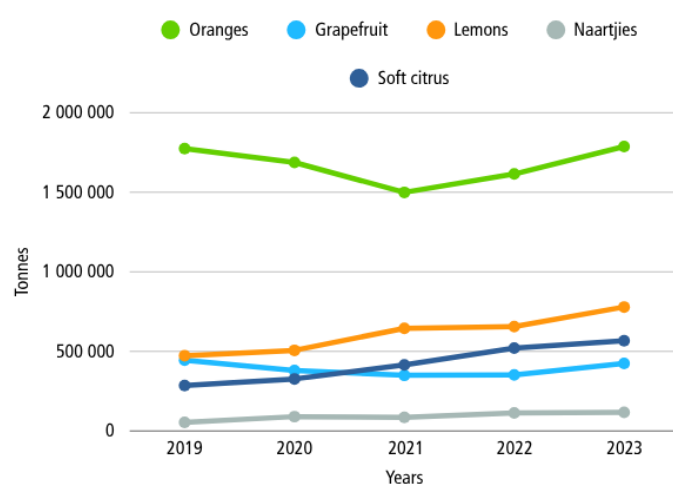


Figure A6.14 Trends in tonnage of different citrus fruits produced, 2019–2023

Source: DALRRD (2024a); Cloete et al. (2024)

The gross value of production of citrus in 2023 was R27.5 billion, with oranges being the largest contributor. This sector plays an important role in employment, employing around 120 000 people.

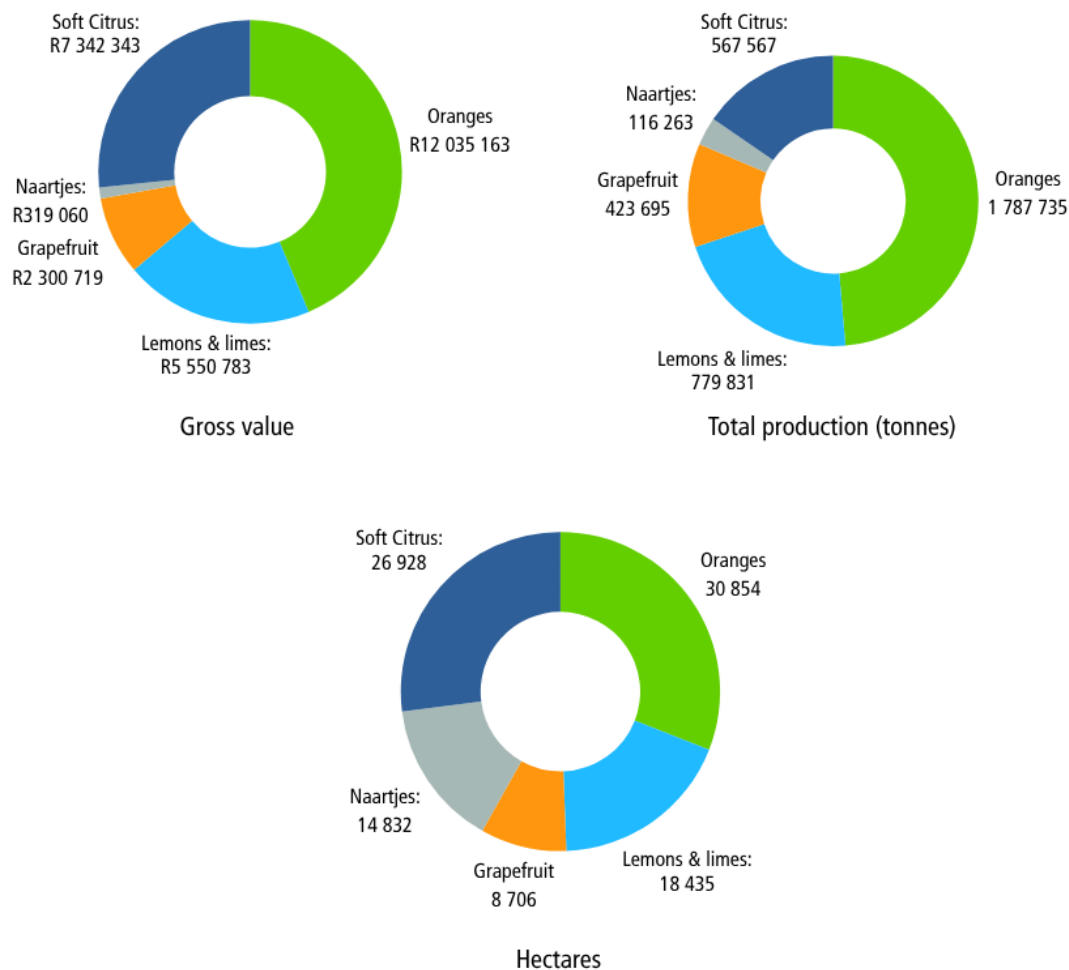


Figure A6.15 Relative gross value of production, total tonnage produced and area under production according to different citrus fruit types

Sources: DALRRD (2024a); Fruit SA (2023)

South Africa has 99 755 hectares under citrus production, with 31% planted to oranges and 27% to soft citrus. Limpopo has 39 634 hectares of citrus orchards, making it the province with the most citrus production. The Eastern Cape and Western Cape respectively account for 26% and 20% of the citrus production area (CGA 2024).

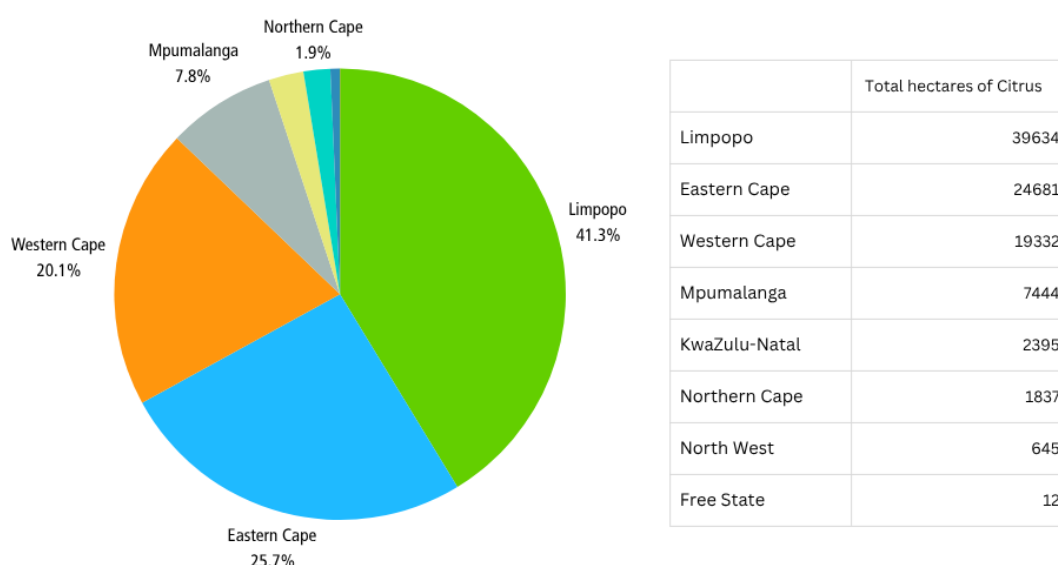


Figure A6.16 Area under citrus production by province
Source: Citrus Growers Association (CGA) (2024); Cloete et al. (2024)

Markets, exports and certification

Citrus is predominantly export oriented, exporting 65% of total production. It is South Africa's single biggest agricultural export by value, contributing 13% of total agricultural export value (Cloete et al. 2024). It is the second-largest exporter, after Spain, of citrus in the world and provides the northern hemisphere with fruit off-season. In terms of volume, the EU imports 36% of SA's total citrus, followed by the Middle East (19%), Southeast Asia (13%), North America (9%) and Russia and UK (each 8%) (CGA 2024).

The value of citrus exports in South Africa increased by 20% from 2022 to 2023, valuing R33.9 billion in 2023 (NAMC 2024a). The EU was the main market, with exports valuing R14.8 billion and within this market, Netherlands was the top market reaching R7.7 billion. Looking specifically at oranges, Netherlands was the top individual market in 2023, accounting for 34% of export value (NAMC 2024b).

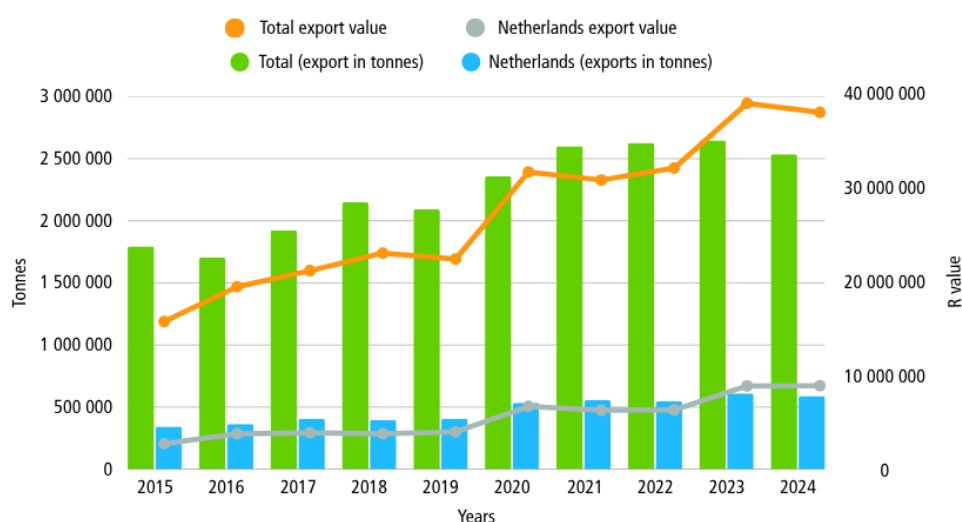


Figure A6.17 Export value and quantity citrus total global exports
Source: ITC data downloaded

Since 96% of citrus farmers register orchards for export to the EU, their regulations are regarded as “the standard”. These regulations require strict adherence to by practices at both farm and packhouse levels, as well as specific load-out temperatures and set temperatures for containers. In recent years, these measures have become increasingly restrictive, despite scientific evidence indicating that the additional measures are unwarranted. South African citrus exports to the EU are subject to inspection both in South Africa and at the port of delivery for a list of phytosanitary pests. On arrival in the EU, consignments are inspected for *Elsinoë* spp., Fruit Fly, False Codling Moth and Citrus Black Spot (Cloete et al. 2024). This places an immense financial burden on producers.

Similarly, to the other sectors, the proposed European Green Deal has a detrimental impact on the citrus industry. Two of the plant protection products (PPPs) on the list are *imidacloprid*, which is used in insecticides for Citrus Greening, and *mancozeb*, which is in fungicides for Citrus black Spot. While climatic conditions and pest prevalence across different regions of South Africa differ, analysis shows that availability of alternative active ingredients will result in a loss of export quality and a resultant reduction in citrus exports. However, given the price elasticity of citrus, a reduction in exports is expected to push up prices, resulting in price premiums and an increase in value of the industry (Cloete et al. 2024).

A6.2.2 Deciduous fruit

Economics, scale of production and location

Deciduous fruit includes pome fruit (apples and pears) and stone fruit (peaches, plums, cherries, apricots and nectarines) in addition to berries. In 2023, the gross value contribution of deciduous fruit amounted to R27 billion, of which R11 billion was generated from apple production (DALRRD 2024a).

Stone and pome fruit

Since 2016, the production of apples has seen a 46% increase, with production in 2023 reaching 1.34 million tonnes. Production improved with 7% from 2022 to 2023, as production was supported by good winter conditions and young trees coming into production (Moobi 2024b). Apples are harvested between January and May, but due to controlled atmosphere, domestic and international markets are supplied all year round (HortGro 2023). There are eight cultivars which make up 91% of area planted.

Pear production showed a 20% increase in production since 2016, reaching 507 550 tonnes in 2023 (HortGro 2022, 2023). Similarly to apple production, the good winter rains and sufficient chill hours resulted in good yields and quality. There are four cultivars which make up 83% of all pear plantings. The 8% drop in production from 2022 to 2023 was due to hail damage in the major producing areas, and as a result farmers are investing in hail nets (Moobi 2024b).

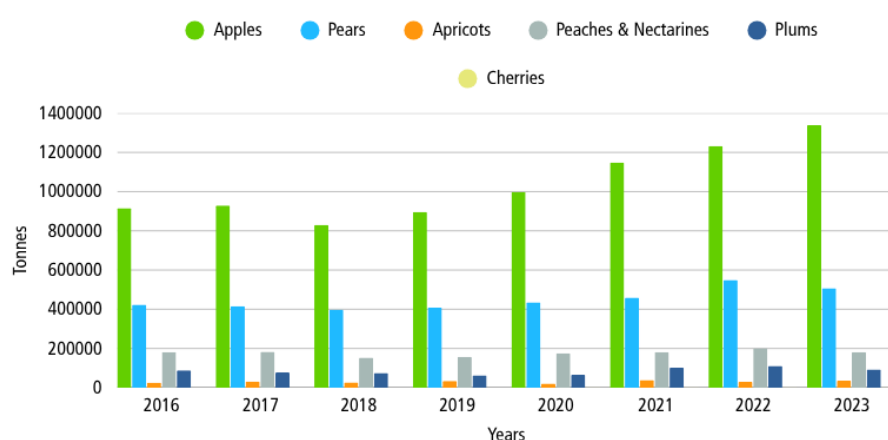


Figure A6.18 Quantity of production of a selection of stone and pome fruits, 2016–2023
Source: HortGro (2023)

Over the past eight years, apricots have grown 36% in total tonnage produced, despite contracting 22% in area. Cherry production has increased by an average of 31% per year since 2016, from 425 tonnes in 2016 to 1 966 tonnes in 2023. The area under cherries has also increased by 176% since 2016.

There are 1 488 producers of pome and stone fruit, providing employment for around 86 000 permanent employees. Apples and pears provide the largest sources of employment, given their scale of production.

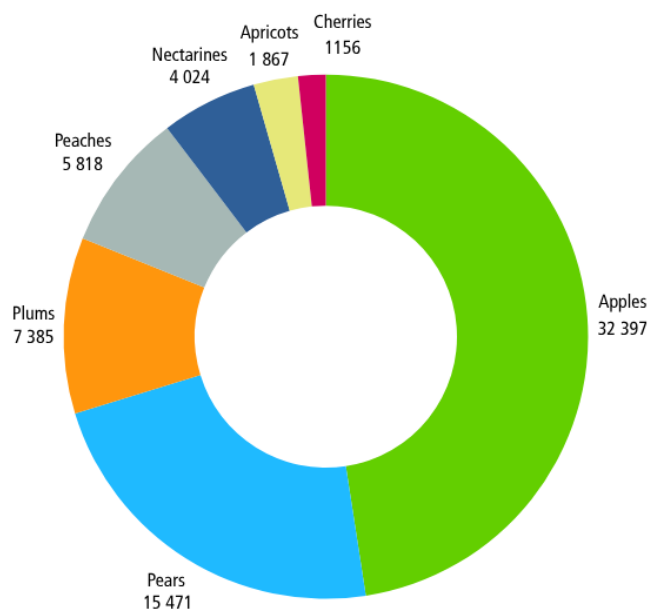


Figure A6.19 On-farm permanent employment according to different stone and pome fruit sectors
Source: HortGro (2023)

Around 54 349 hectares of land is dedicated to orchards, with production primarily occurring in the Western Cape and certain areas of the Eastern Cape. The Klein Karoo is the main location to produce apricots and peaches, while Ceres, Groenland, Villiersdorp and the Langkloof specialise in apples, pears and nectarines.

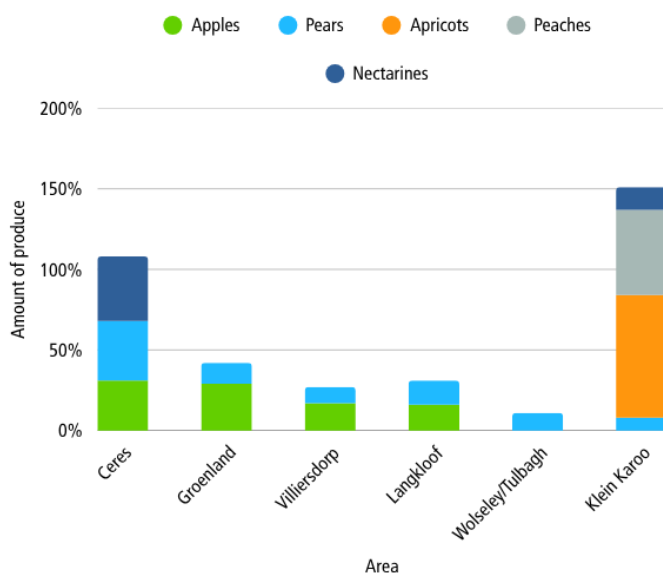


Figure A6.20 The locations of the fruit production areas
Source: HortGro (2022)

The area under apples and pears has remained unchanged and reports suggest that growers are focusing on investments in alternative energy installations and therefore limiting investment in area

expansion. High electricity tariffs impact growers who rely on the national grid for irrigation, packing and cooling operations (Moobi 2024b).

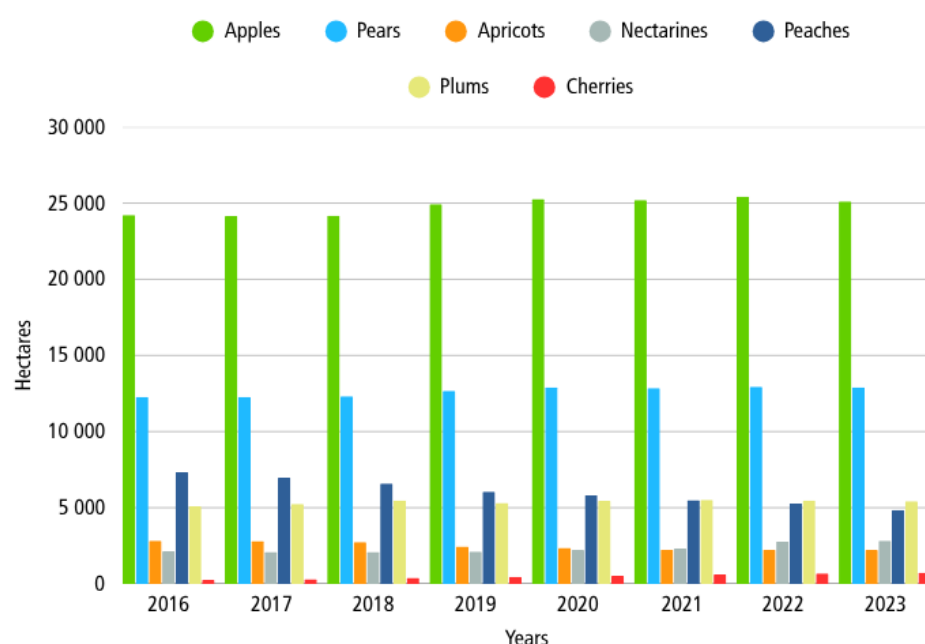


Figure A6.21 Area under pome and stone fruit production, 2016–2023
Source: HortGro (2023)

Berries

The latest Bureau for Food and Agricultural Policy (BFAP) report shows that blueberries have been the fastest-growing fruit industry in South Africa over the past 30 years, due to strong yield improvements and even greater growth in area planted (Meyer et al. 2025). Over the past seven years, blueberry production has increased on average by 36% per annum and experienced a 500% increase in area planted to blueberries (HortGro & SAPBA 2018; HortGro 2023).

In 2023, berries produced 0.7% share of South Africa’s agricultural income (R3.2 billion) with 69% stemming from blueberries, 23% from strawberries and 8% blackberries and raspberries (Pienaar 2024).

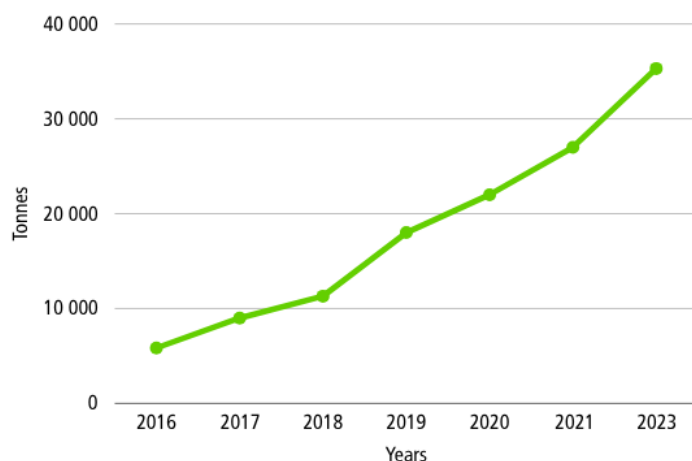


Figure A6.22 Production of blueberries, 2016–2023

Sources: Western Cape Department of Agriculture (2019); Sikuka (2020); NAMC (2024b); Fruit SA (2023)

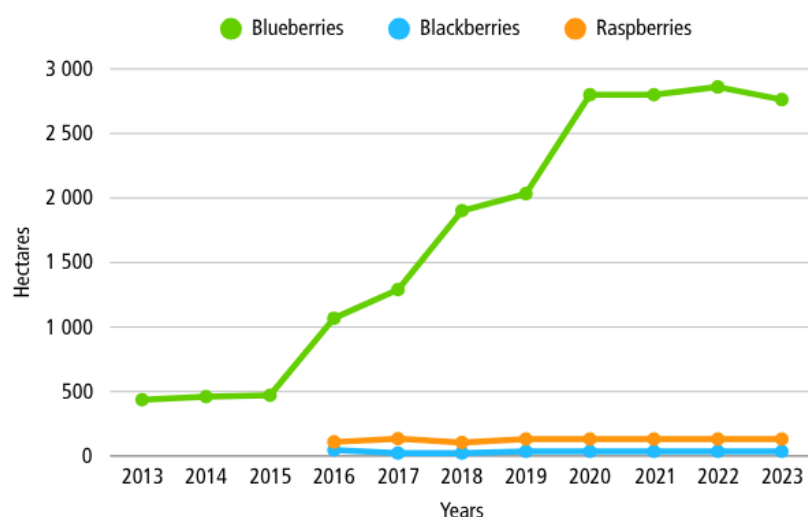


Figure A6.23 Area under production of blueberries, blackberries and raspberries, 2013–2023

Sources: HortGro & SAPBA (2018); HortGro (2023)

There are currently 2 929 hectares of blueberries under production, with 60% of berry production taking place in the Western Cape, 15% in Limpopo and 10% in the North West (Western Cape Department of Agriculture 2019). Being very labour intensive, it is estimated that for every hectare of blueberries under production, it provides, on average, direct employment of 2.64 fulltime equivalent workers (Western Cape Department of Agriculture 2019).



Figure A6.24 Percentage distribution of locations of blueberry production

Source: Western Cape Department of Agriculture (2019)

Markets, exports and certifications

Pome and stone

Reports show that 40% of deciduous fruit production exported (HortGro 2023). In total, 91% of pome fruit income is generated from domestic fresh sales. The Far East and Asia are the main export market for apples (35% total exports), while Europe is the main export market for pears (28% total exports) (HortGro 2023). Similarly, 82% of the stone fruit industry is generated from fresh sales. The largest exports for stone fruit include the Middle East at 54% for apricots, the UK at 41% and 46% for peaches and nectarines, Europe being the main export destination for plums (47%) and the UK for cherries (59%) (HortGro 2023).

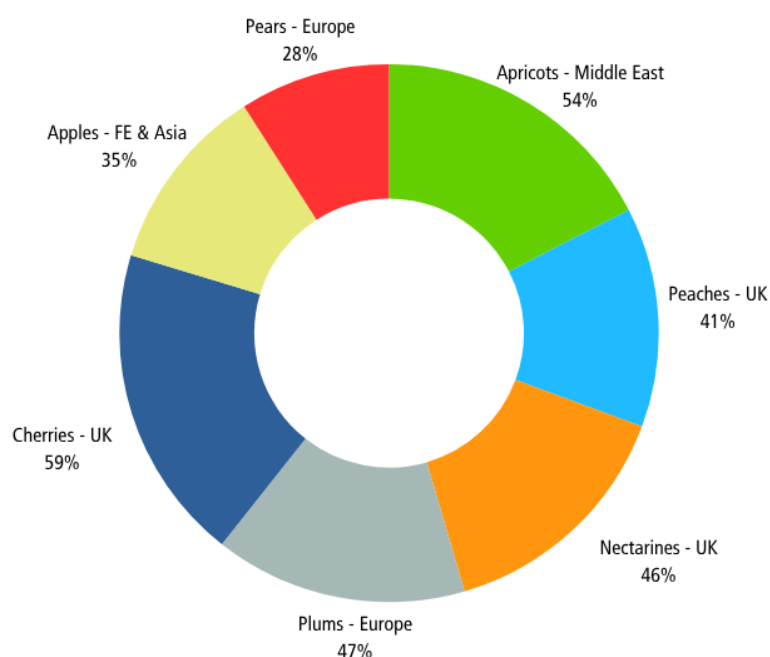


Figure A6.25 Largest destinations of each type of deciduous fruit export
Source: HortGro (2023)

Pome fruit exports faced the same port and logistical challenges as other deciduous fruits in 2022. Some produce was re-routed to Port Elizabeth for export, and this added additional costs to growers. The industry has also been affected by the Russia-Ukraine conflict, given that 8% of South African apples and 18% of pear exports by volume were bound for Russia in 2021. Despite being able to lengthen the export window due to controlled atmosphere storage, exports are still dependent on optimal market conditions, fruit quality and storage costs, which determine the export window (BFAP 2022). Since India's government approved in-transit cold treatments and China granted market access in 2021, there has been significant market growth to these two countries (Moobi 2024b).

Like other sectors, exported fruit must meet strict phytosanitary regulations and certifications. The proposed European Green Deal also has a potential impact on the pome industry given the EU expiration of approval of plant protection products, specifically the fungicide *Mancozeb*. While there are alternatives available, they are more expensive and require more spraying and it is estimated that this translates to an additional 5% in producers' costs. The EU is of significance for exporting pears, as it is the single biggest market for pears (28% of exports) and therefore the industry cannot avoid this market. However, only 8% of exports of apples are destined for the EU and so this could be avoided. If the Green Deal is implemented, projections estimate a decline of 3% of total pome production because of the decline in volume and quality, with area under apples declining by 3.5% and pears 3% (Cloete et al. 2024).

Berries

Blueberries are focused on the export market, with around 72% destined for export. Approximately 12% of total production is sold locally on South Africa's fresh markets, and the remaining 16% is sold for processing (BFAP 2022). Blueberry exports have increased by approximately 37% per year since 2011, corresponding with production growth. In value terms, exports grew from R133 million in 2013 to R1.058 billion in 2018 (Western Cape Department of Agriculture 2019). BFAP reports that global

demand is still strong, despite the 2023 supply shock when Peru did not have the volumes and the resultant price increases. There is still a margin squeeze for blueberry farmers, and they do not have much room for strategic investments and opportunities to expand production.

The industry has largely been built with the UK and Netherlands's fresh berry market in mind, with Netherlands overtaking the UK to become the biggest export market in both value and volume after 2019 (BFAP 2022). South Africa is the tenth largest producer of blueberries globally. Price pressure is influenced by the influx of Peruvian blueberries into South Africa's traditional export markets, along with occasional difficulties in maintaining fruit quality during extended travel times due to port congestion (BFAP 2022).

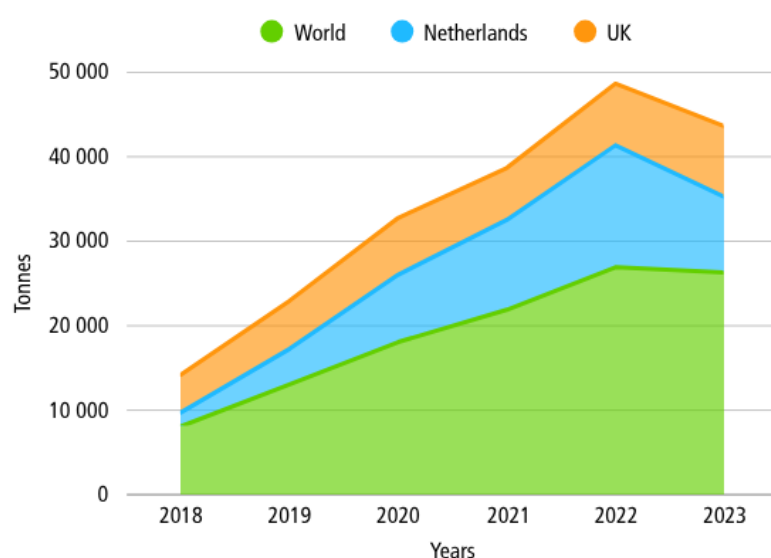


Figure A6.26 Blueberry exports, 2018–2023

Source: SARS Trade data downloaded: HS code for berries 08104000

A6.2.3 Sub-tropical fruit

Economics, scale of production and location

The category of sub-tropical fruit includes fruit such as avocados, bananas, granadillas, litchis, guavas, mangos, papayas and pineapples. It not surprising that the cultivation of sub-tropical fruit is located predominantly in Limpopo, Mpumalanga and KwaZulu-Natal, given the specific climatic requirements of warmer conditions, minimal temperature fluctuations and no frost to cultivate the fruit.

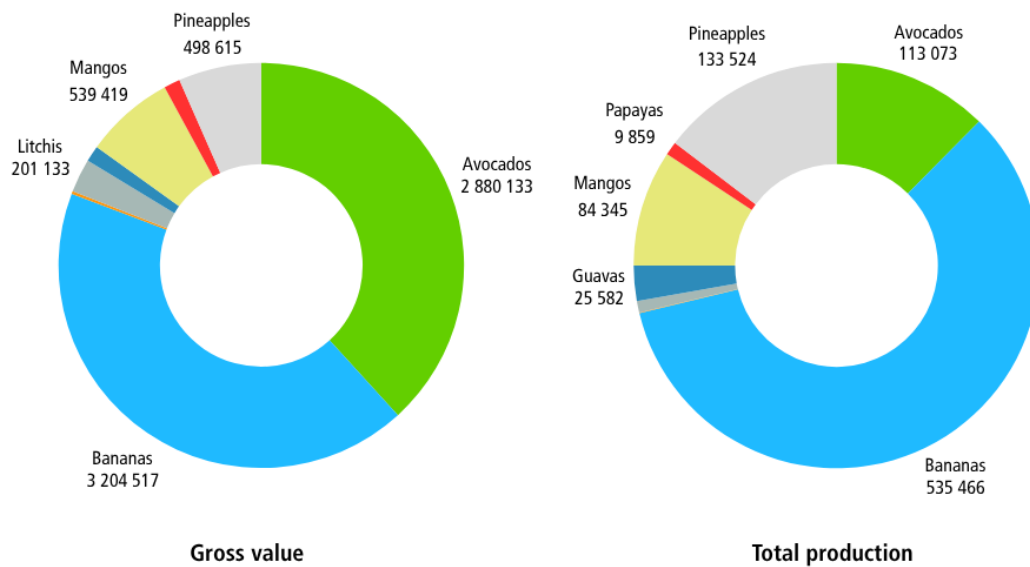


Figure A6.27 Gross value of production of a selection of sub-tropical fruit and the total production
Source: DALRRD (2024a)

According to the Abstract of Agricultural Statistics, total production of sub-tropical fruit was over 910 000 tonnes, with a total gross value of R7.5 billion (DALRRD 2024a). Bananas (R3.2 billion) and avocados (2.88 billion) are the highest contributors, making up 80% of total value. Bananas produce the greatest tonnage, producing 535 466 tonnes in 2023 with avocados (113 073 tonnes) and pineapples (133 524 tonnes) following.

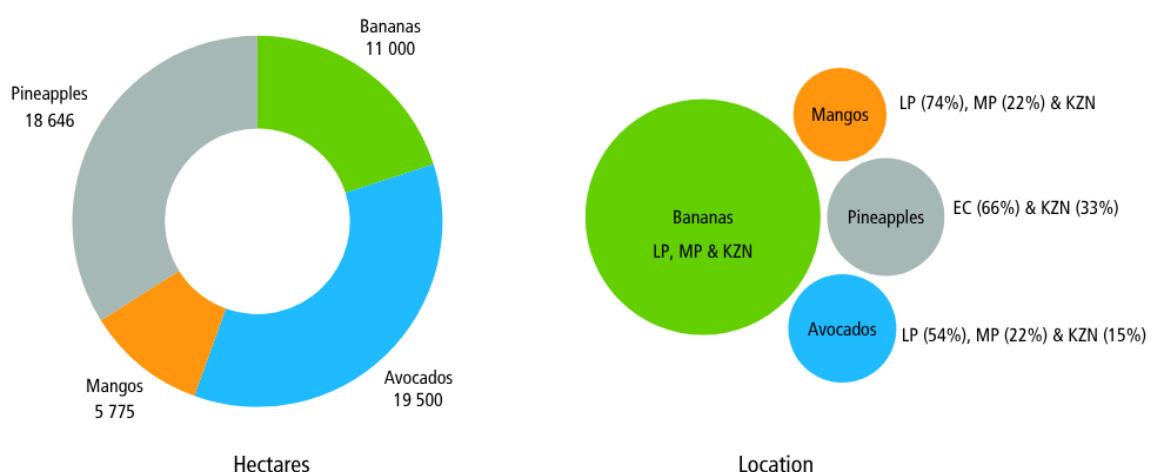


Figure A6.28 Location and area under production of selected sub-tropical fruit
Source: Fruit SA (2023); SAMGA Tree Census (2024)

Avocado gross value of production grew by 238% from 2012–2022 and despite weather difficulties, high density planting and cultivar development is expected to drive growth even more (BFAP 2022). The industry reports a 3-year average annual production of 146 500 tonnes (SAMGA 2024). Over the past ten years, avocado area increased from just over 12 000 hectares in 2012 to 19 500 hectares in 2023, resulting in growth of 63% over the period, or average annual growth of 2.4% (BFAP 2022).

Markets, exports and certifications

Fresh sub-tropical fruit is mainly produced for the domestic market, especially for bananas which cannot meet the bright yellow standards needed for export market (Farmers Inside Track podcast, 2024). However, avocado production is export-oriented, with 45% of production exported in 2021 (NAMC 2023). The EU remains the largest export market, with the Netherlands (62.5% of total exports) and the UK (18.1%) being the two primary destinations. A small proportion of mangoes and pineapples are produced for the export market, with 5% and 2% of total production being exported, respectively. Between 70% and 80% of the pineapple crop is destined for the processing market, with the remainder being predominantly sold on the local markets. Around 64% of mango production is used for processing (dried, achar and juice), with 23% reaching the local fresh market (SAMGA 2024).

A6.2.4 Nuts

Economics, scale of production and location

While macadamias and pecans are the most prominent tree nuts produced in South Africa, almonds, pistachios and walnuts are also produced in small quantities.

Over the past decade, both macadamias and pecans have experienced significant expansion. The area planted has increased by approximately 200%, reflecting an average annual growth rate of 13% from 2012 to 2021 (BFAP 2022). There is currently 68 556 hectares planted to macadamias and 37 035 hectares under pecan nuts (SAPPA 2024; SAMAC 2024). Due to the aggressive new plantings and the very long period from establishment to full bearing, it is anticipated that going forward volume growth will mostly reflect existing plantings from now until 2031 (BFAP 2022).

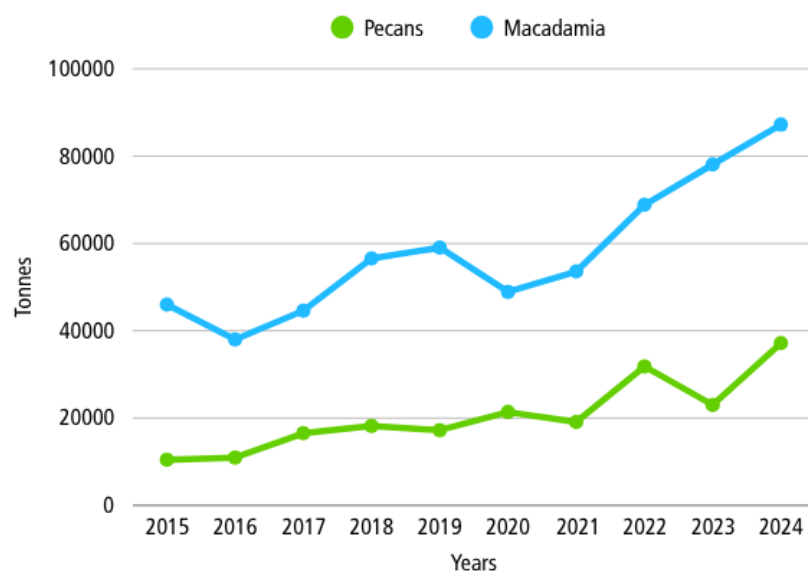


Figure A6.29 The volume of macadamia and pecan nuts produced, 2015–2024
Sources: SAPPA (2024); SAMAC website

In 2024, macadamia nut production reached 87 227 tonnes, with pecan nuts producing 37 000 tonnes (SAPPA 2024; SAMAC 2024). Macadamia nut production grew by 90% from 2015–2024, while pecan nuts production grew by 255%. Macadamia production employs 43 500 permanent employees and 40 000 seasonal workers.

Most of pecan nut production takes place in Vaalharts in the Northern Cape, followed by Free State and other parts of the Northern Cape. Macadamia nuts are grown predominantly in Mpumalanga, followed by KwaZulu-Natal.

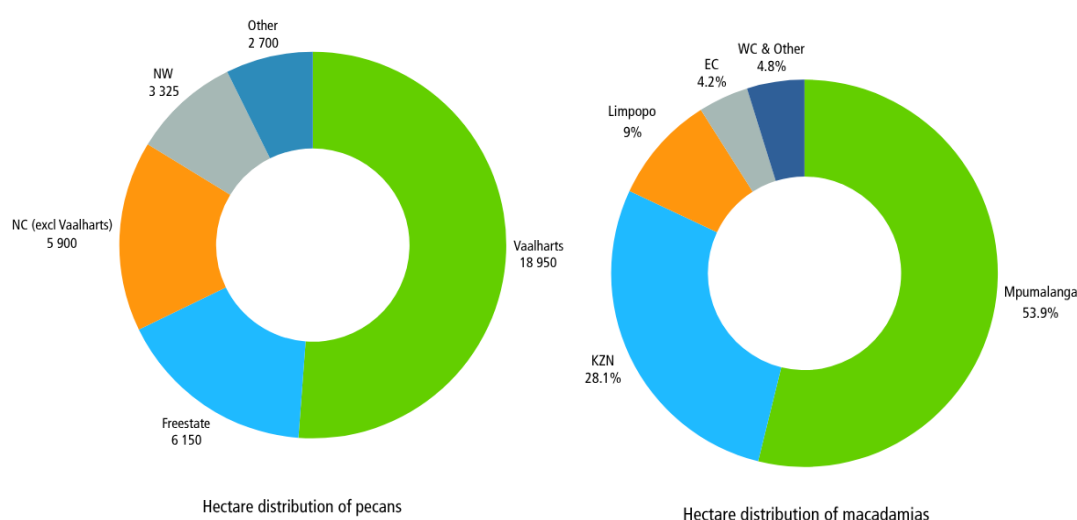


Figure A6.30 Location of macadamia and pecan nut production
Sources: SAPPA (2024); SAMAC website

Markets and exports

South Africa is the leading global exporter of macadamia nuts, exporting 66% of total production. The 2023 year saw a 23% growth in exports, with the nut-in-shell sales being responsible for this growth. China is the fastest growing market for macadamia nuts (Nut in Shell – NIS) and currently consumes 30% of South African production. The U.S. and Europe are the main importers of macadamia kernels, while China, Vietnam and Hong Kong are the main importers of NIS (SAMAC).

However, in 2023, macadamia prices reached historic lows due to a combination of lower demand and increase in global crop due to new planting. In 2023, farmers achieved on average US\$8.25/kg for kernel, even lower than 2022 average price of US\$11.50 and US\$16/kg in 2021. Although prices are on an upward trajectory, they are not expected to reach the 2018 peak prices of US\$20/kg (Botha 2024).

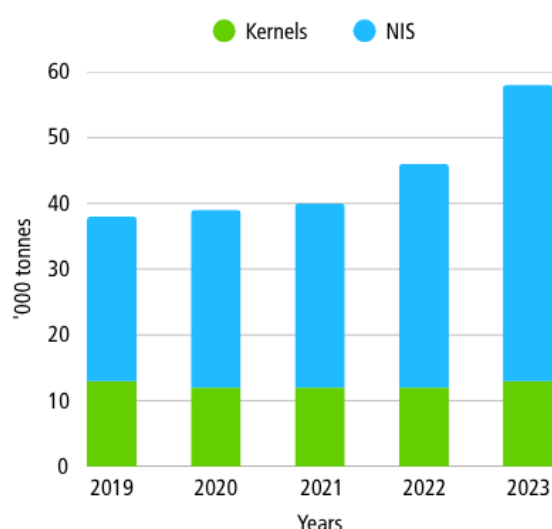


Figure A6.31 Exports of macadamia nuts, 2019–2023

Source: SAMAC website

South African pecan nuts are a considerable global player, being the third largest producer in the world and making up 23% of global production. In addition, 92% of total production is exported.

For the nut-in-shell pecan market, China is the predominant export market, importing 32 620 tonnes in 2024 which made up 98.4% of total NIS exports. For the shelled pecan market, the UK and Europe imported 92% of shelled pecans, with the UK importing 290 tonnes, the Netherlands 220 tonnes and Germany 40 tonnes (SAPPA 2024).

A6.2.5 Fruit and nuts: Role-players and institutions

Figures A6.32 and A6.33 highlights the key role-players within the fruit and nut sector. Further detail is contained in Annexure 7.



Figure A6.32 Key role-players within the fruit and nut sector

Sources: Citrus Growers Association of South Africa (<https://www.cga.co.za/>); Citrus Research International (<https://www.citrusres.com/>); South African Sub-Tropical Fruit Growers Association (Subtrop) (<https://www.subtrop.co.za/>); South African Avocado Growers' Association (SAAGA) (<https://avocado.co.za/>); South African Litchi Growers' Association NPC (SALGA) (<https://litchisa.co.za/>); SAMGA South African Mango Growers Association (<https://mango.co.za/>); HortGro (<https://www.hortgro.co.za/>); BerriesZA (<https://www.berriesza.co.za/>); Macadamias South Africa NPC (SAMAC) (<https://samac.org.za/>); South African Pecan Nut Producers Association NPC (SAPPA) (<https://www.sappa.za.org/>); Fresh Produce Exporter's Forum SA (<https://www.fpef.co.za/>)



Figure A6.33 Role-players across all horticulture sectors

Sources: Fruit SA (<https://fruitsa.co.za/>); NAMC (<https://www.namc.co.za/>); Fresh Produce Exporter's Forum SA (<https://www.fpef.co.za/>)

A6.3 Vegetables

A6.3.1 Economics, area under production and location

The gross value of vegetable production for 2023 was R34 billion, with potatoes, and green mealies accounting for 32% and 23% of the total value, respectively (DALRRD 2024a). Figure A6.34 below shows a selection of other vegetables.

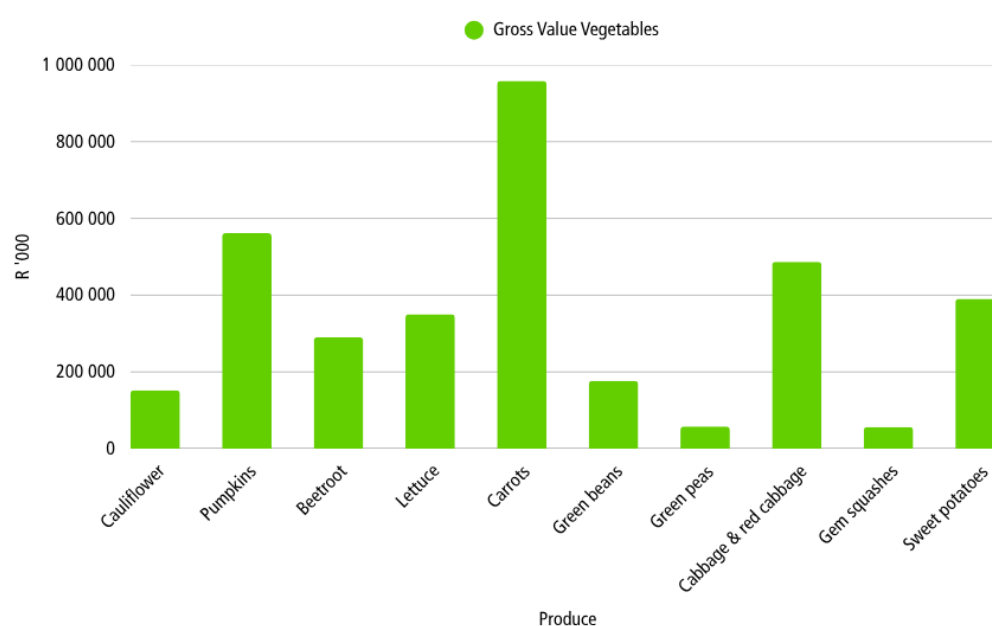


Figure A6.34 Gross value for selected vegetables

Source: DALRRD (2024a)

Figure A6.35 shows the relative tonnage produced of selected vegetables over the past 10 years. All the selected vegetables have shown growth, except for tomatoes which decreased by 9%. Green corn grew by 18%, cabbages by 29% and sweet potatoes by 26%, with onions remaining consistent with a small 4% growth (DALRRD 2024a).

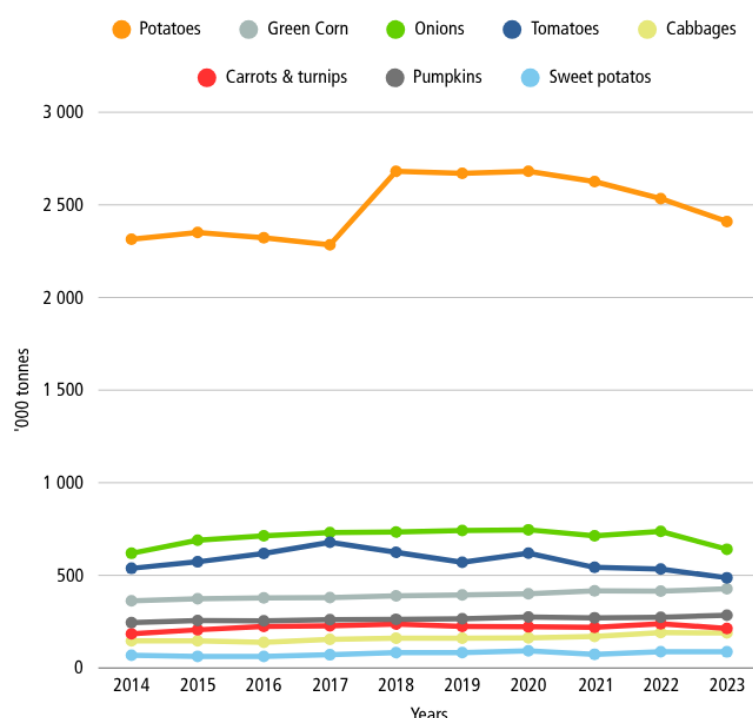


Figure A6.35 Volume of selected vegetables produced, 2014–2022
Source: DALRRD (2024)

Potatoes

In 2023, 49 841 hectares was planted for potato production, and 11 219 hectares planted for seed potato production (Potatoes SA 2024).

There is a specific window for planting and harvesting, and due to differing climate conditions and diverse soil types across South Africa, potatoes can be produced all year round. There are 16 distinct potato-production regions with the Free State, Limpopo, Western Cape being the top three locations. There are an estimated 570, predominantly commercial, potato farmers employing 50 000 permanent and 60 000 seasonal employees (Adama 2022). In total, 84% of potato plantings is under irrigation.



Figure A6.36 Location of potato plantings across the provinces
Source: Potato South Africa (2024)

Tomatoes

Tomatoes rank among the most widely consumed fruits, with the sector primarily dominated by commercial farmers, comprising 95% of the industry. An estimated 75% tomato planting takes place in Limpopo, followed by Mpumalanga and the Eastern Cape (NAMC 2024).

Figure A6.37 shows trends in the production and area harvested from 2014–2023. The highest production period over the decade was in 2017, reaching 679 000 tonnes. The decline in tomato production in 2023 has been attributed to unfavourable climate conditions and high production costs. Over the decade, the production of tomatoes has declined by 9%.

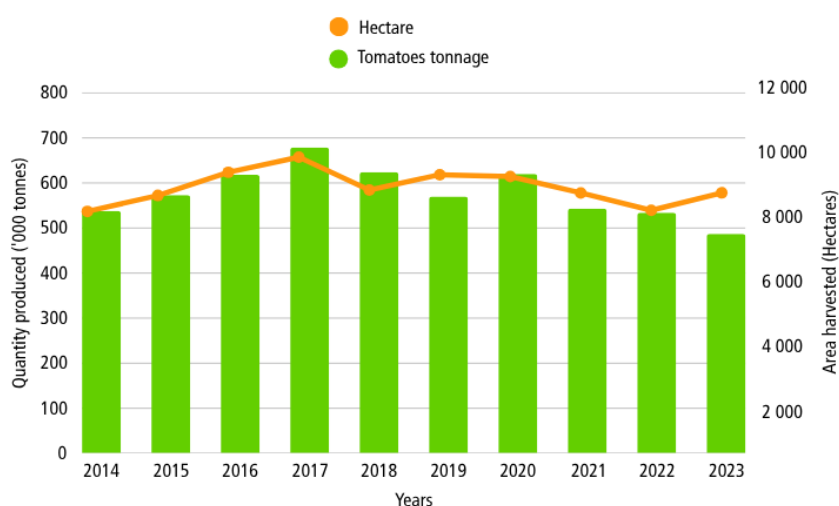


Figure A6.37 Volume tomatoes produced and the area under production
Source: FAOSTAT data (FAO 2025); DALRRD (2024a)

A6.3.2 Markets

Potatoes

Fresh potatoes made up 76% of the total production in 2023, with 15% going to processing, 4% fresh export, 4% certified seed and 1% certified export seed (Potato SA 2024).

Figure A6.38 shows the quantity of potatoes sold on the major fresh produce markets around the country and the corresponding price. The average price decreased from 2021 to 2022 by 11.1% while quantity of sales increased by 4.5% over the same time (DALRRD 2024a).

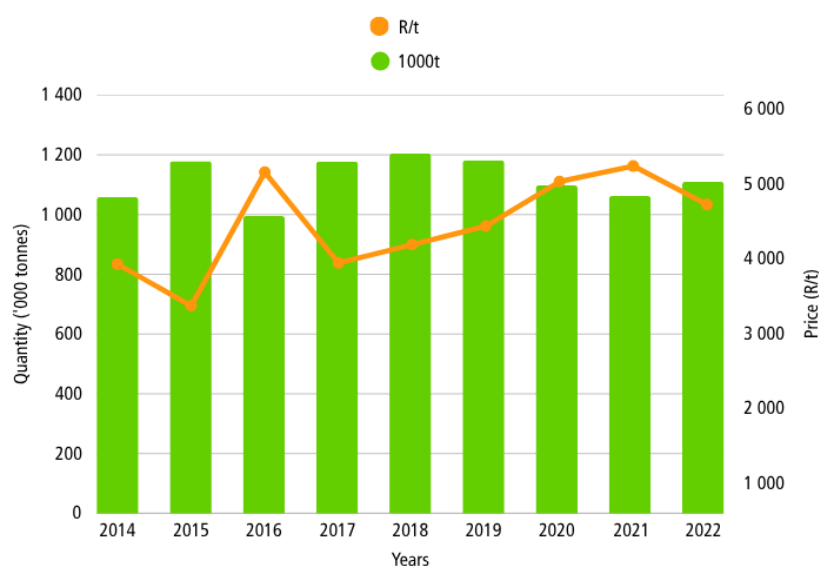


Figure A6.38 Volume of potatoes sold and corresponding unit price
Source: DALRRD (2024a); Potato South Africa (2024)

Tomatoes

Almost 50% of tomatoes produced are sold on the local fresh market. As expected, the decline in production harvested in 2022 and 2023 corresponded with a decline in the quantity of tomatoes sold on the fresh market produce. However, prices increased to R9 721/tonne in 2023 (DALRRD 2024a).

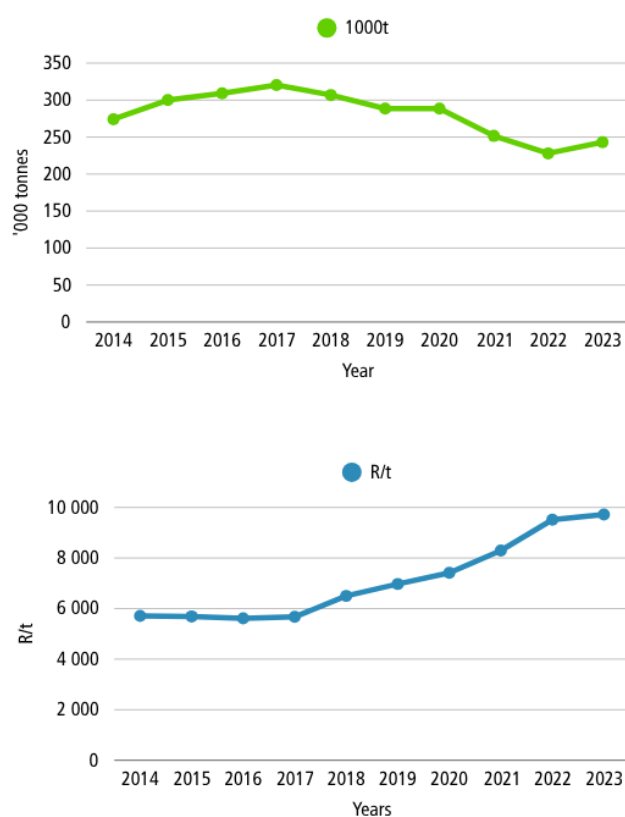


Figure A6.39 Tomato sales on local markets and corresponding unit price
Source: FAOSTAT data; DALRRD (2024a)

Around 18% of tomatoes are exported, with Sub-Saharan Africa importing most of the produce (Zimbabwe: 34%; Eswatini 24% and Namibia 19%).

A6.3.3 Role-players and institutions

Figure A6.40 shows the role-players within the vegetable sector. Annexure 7 details further information.

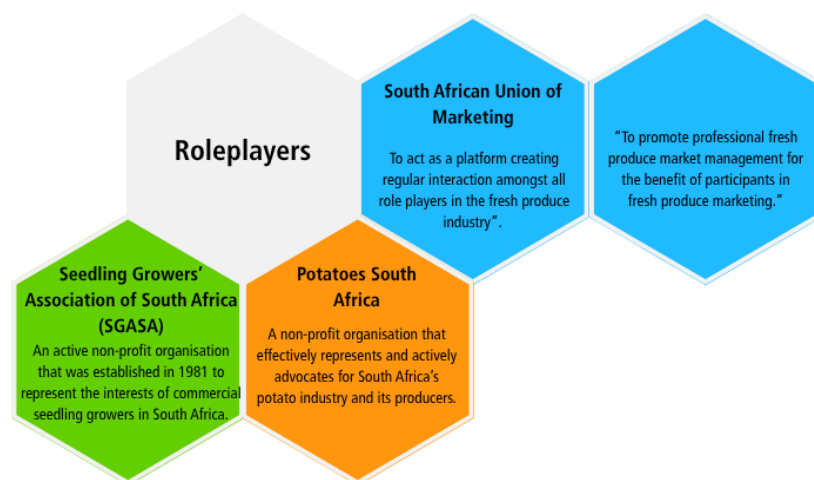


Figure A6.40 Key role-players within the vegetable sector

Sources: South African Union of Marketing (<http://www.saufm.co.za/>); Potatoes South Africa (<https://www.potatoes.co.za/>); Seedling Growers' Association of South Africa (SGASA) (<https://southafrica.co.za/seedling-growers-association-of-south-africa.html>)

A6.4 Other horticulture produce

A6.4.1 Rooibos Tea

Economics, location and area under of production

In 2023, the volume of rooibos tea produced was 22 600 tonnes, with a gross value of R362 million (DALRRD 2024a). It provides employment for an estimated 8 000 workers in primary production in addition to upstream activities (processing, retailing, packaging). However, trends show a decrease in gross value over the past six years despite production increasing. Prices averaged around R67/kg in 2018, declining to R51.80/kg in 2019, to a mere R25.25/kg in 2020 (Britz 2023).

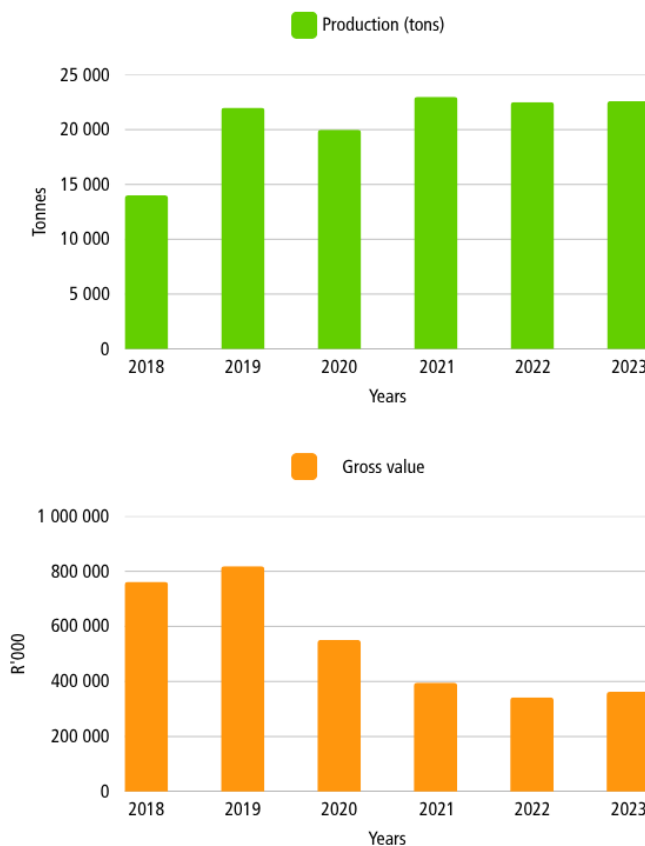


Figure A6.41 Production of rooibos harvested and the gross value of rooibos, 2018–2023
Sources: SA Rooibos; DALRRD (2024a)

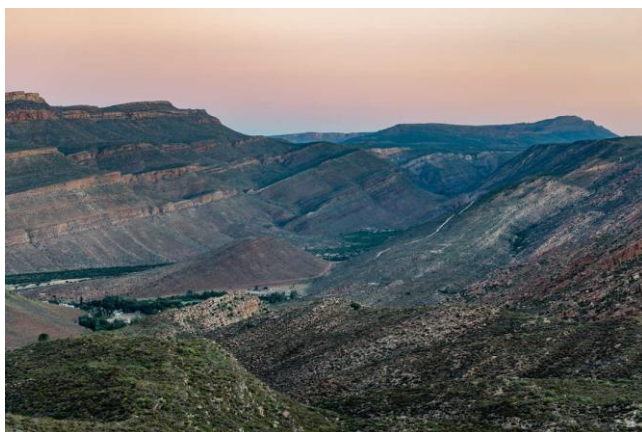
There are roughly 300 commercial farmers, 170 small-scale farmers in Wupperthal and 54 small-scale farmers in Moedverloor and Heiveld and 80 tea courts (on farms and in villages). A tea court is a flat, open area where the harvested and cut rooibos is spread out to allow for natural fermentation and drying. There is around 67 000 hectares under production and rooibos is primarily grown in the Cederberg region of the Western Cape and the Bokkeveld plateau in the Nieuwoudtville area of the Northern Cape. This has grown significantly from 1993, when there was just 13 000 hectares under production (Barends-Jones 2020). Both Heiveld and Wupperthul Rooibos Co-operatives are organically and Fairtrade certified.



Figure A6.42 The location of rooibos production
Source: Britz (2023)

Small Scale Rooibos Farmers – case study

There are two Fairtrade certified associations of small-scale rooibos producers: the Wupperthal and Heiveld cooperatives. The Wupperthal has 170 members and produces 80–100 tons per year while Heiveld has 54 small-scale farmers (Avaclim 2020; Raynolds and Ngcwangu 2009). Heiveld Co-operative is situated in the Bokkeveld Plateau near Nieuwoudtville in the Northern Cape, while Wupperthal is in the Cederberg Mountains in the Western Cape.



The village of Wupperthal, nestled in a valley in South Africa's Cederberg Mountains, sits at the heart of rooibos country
Trenchard (2023)

Both cooperatives use traditional production techniques where wild Rooibos is harvested and where small numbers of planted shrubs are cultivated without chemicals, harvested by hand, and left to rejuvenate between harvests (Raynolds and Ngcwangu 2009).



Left: Members of rooibos farming co-operative harvest their crop in the Cederberg Mountains, South Africa. Right: Farming cooperative drying rooibos on tea court in Wupperthal, South Africa

Trenchard (2023)

Climate smart regenerative agriculture practices

An important contribution from the Heiveld Co-op has been the formulation of guidelines for the harvesting of wild rooibos, which draws on the traditional community knowledge (UNDP 2015). After the 2003–2006 drought, the Heiveld Co-op members began experimenting with soil and water conservation measures:

- Collecting and storing water during winter rains to use in the summer
- Removing alien invasive species to conserve water and protect the fire-adapted fynbos ecosystem from hotter and longer fire (UNDP 2015)
- Mulching the rooibos fields
- Constructing contours on lands and roads to enhance the infiltration of rainwater and prevent soil erosion (Avaclim 2020)
- Varying the frequency and intensity of ploughing
- Creating shelterbelts from native vegetation which have been particularly effective in protecting young rooibos from damaging high winds. Shelterbelts also help retain soil and soil moisture, create “seed nurseries” by trapping native seeds, preserve fynbos vegetation and enhance soil carbon

Economic and social benefits

Wupperthal and Heiveld have acquired organic certification allowing them to sell both, Fair Trade and organic, certified Rooibos tea (Raynolds and Ngcwangu 2009). The economic benefits for Heiveld are significant – tripling their earnings from US\$1.35 to US\$4.00 per kg of Rooibos by switching from conventional to Fair Trade markets. Over the past decade, Wupperthal producers have seen similar price increases, with an initial price increase in the 1990s and then another rise with their FLO certification.

The cooperatives also access social premium benefits from the Fair Trade Labelling Organisation (FLO) social premium (US\$0.68 per kg of processed tea in 2005). Wupperthal and Heiveld have used their social premiums to fund farm and processing improvements, local schools, and other community projects (Raynolds and Ngcwangu 2009).

Markets, exports and certification requirements

Looking at the markets, 44% of rooibos tea is exported, with Japan, France, Germany, the Netherlands, the UK and U.S. being the top destinations over the past three years (SA Rooibos Council 2024). Over the years, annual exports have grown from 500 tonnes in 1996, to 6 552 tonnes in 2013 to 9 970 tonnes in 2023 (SA Rooibos Council 2024). The export value of the industry was R936 million in 2019.

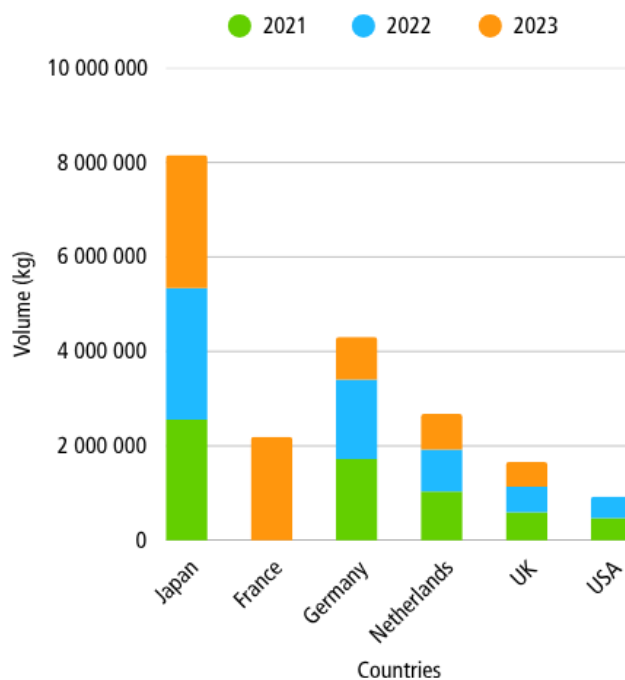


Figure A6.43 Export quantities to top five destinations, 2021–2023
Source: South African Rooibos Council (2024)

The Rooibos industry adheres to multiple international and national standards for production and processing. Producers have the option to obtain certification according to the following standards to ensure market assurance (SA Rooibos Council 2024):

Standards and certification			
Standards		Certification	
GLOBALG.A.P. is a farm assurance program, translating consumer requirements into Good Agricultural Practice.	Global-GAP	Rainforest Alliance	In 2021 Rainforest Alliance and the Union for Ethical Biotrade collaborated to launch the RA – UEBT Herbs and Spices program inclusive of Rooibos.
The whole chain of organic production is inspected and certified, including food processing, distribution and retailing.	USDA organic	Union for Ethical Biotrade (UEBT)	
Improve food safety management and product quality with HACCP (Hazard Analysis and Critical Control Points) certification	HACCP	Sustainable Agriculture Network	The Sustainable Agriculture Network (SAN) is a global network transforming agriculture to secure a sustainable future for food, nature and rural communities.
The Canada Organic Regime (COR) requires mandatory certification to the Canadian Organic Standards for organic products (food for human consumption, feed, and seed).	NOP COR organic	Fairtrade International	Fairtrade International is a product-oriented multi-stakeholder group aimed at promoting the lives of farmers and workers through trade.
This is a compulsory certification for export and marketing of organic products in Japan and certifies agricultural and zootechnical products, processed products for human and animal consumption.	Japan Agricultural Standards	Union for Ethical Biotrade (UEBT)	The new programme recognises UEBT's expert knowledge of ethical sourcing of ingredients from biodiversity, including expertise on good practices for wild collection. It also harnesses the decades-long experience of Rainforest Alliance and UTZ in sustainable agriculture certification.
Used on products that have been certified as organic by an authorised control agency or body of the European Union (EU).	EU Organic		
FSSC 22000 contains a complete certification Scheme for Food Safety Management Systems based on existing standards for certification.	FSSC 22000		
ISO's food safety management standards help organizations identify and control food safety hazards.	ISO 22000		

Figure A6.44 Standards and certification options available to rooibos producers

Source: Adapted from South African Rooibos Council (2024)

A tangible way to show that the rooibos industry is rooted in sustainable practices is through participation in third-party sustainable certification and the following are available to rooibos producers.

A6.4.2 Fynbos flower industry

Economics, location and area of production

The gross value of total cut flower industry is R2.5 billion, but this report deals with information on fynbos flower industry only. According to Cape Flora SA, the fynbos flower industry produces 81 million stems per annum over 1 271 hectares of production. Of this, 62% of flowers cultivated is proteas (Viljoen 2024). The sector provides direct employment for 2 500 and is located in the Western Cape.

Markets, exports and certification requirements

The fynbos flower industry is directed at the export market with 81% of cut fynbos being exported. It is valued at R766 million, with the EU being the main destination (67% of all exports), followed by the Middle and Far East (24%) (Viljoen 2024).

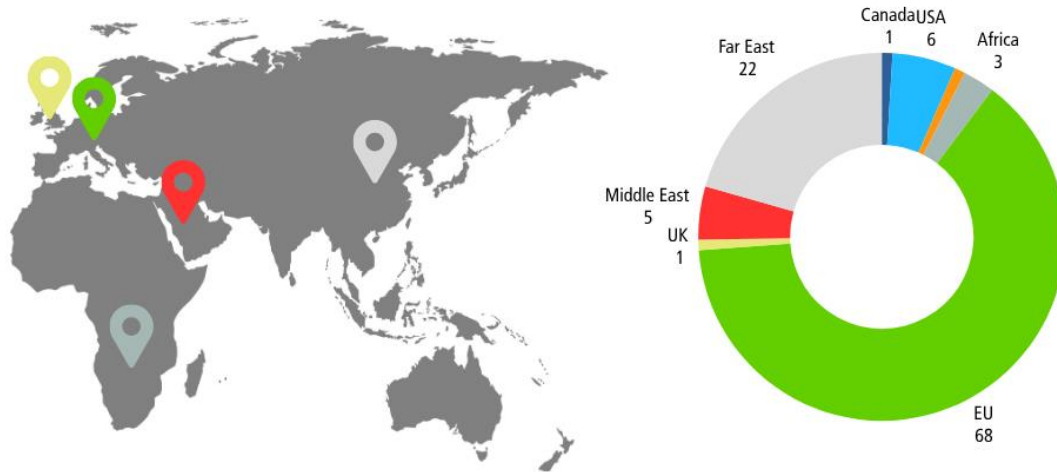


Figure A6.45 Destinations of fynbos flower exports
Source: Viljoen (2024)

Role-players and institutions

The South African Rooibos Council (SARC) is an independent organisation, responsibly promoting rooibos and its attributes to the consumer and protecting the interests of the rooibos consumer and SARC stakeholders supported by effected research and communication (SA Rooibos).

Cape Flora SA, a non-profit company (NPC) established in 2005, is committed to identifying and addressing the strategic needs of the fynbos and protea industry. Their aim is to pursue a sustainable increase in the demand for, and supply of, high value/high quality fynbos products to international markets to the benefit of all role-players in the South African fynbos industry.

ANNEXURE 7: Network Analysis

Various sectors in South Africa's agri-food system are actively in pursuit of the transition towards climate smart agriculture (CSA). Stakeholders implement diverse practices to enhance resilience, sustainability and productivity; from livestock and wool production to pork and horticultural systems. Similarly, across the value chain, producers, processors, research bodies and exporters are adopting CSA-aligned approaches. These include regenerative grazing, integrated crop-livestock systems, efficient water use, sustainable feed solutions and advanced waste management. Emphasis is also placed on sustainable financing, environmental stewardship, capacity building, precision farming and traceability. Across both smallholder and commercial operations, CSA efforts reflect a collective commitment to reducing emissions, conserving resources and fostering long-term climate resilience in food production systems. This chapter looks at how different stakeholders and institutions such as government, industry and farmer bodies, research entities and others are involved in climate smart agricultural activities.

A8.1 Grain (summer and winter grains and oilseeds)

	Main role players	Key focus areas	Climate smart activities	Examples
Government bodies	• Department of Agriculture, Land Reform and Rural Development (DALRRD) • South African Bureau of Standards (SABS) • Department of Environmental Affairs (DEA) • National Agricultural Marketing Council (NAMC) • South African Revenue Service (SARS) • Land Bank • Provincial Departments of Agriculture • Transnet	• Policy and regulation • Environmental protection, biodiversity conservation • Standards and certifications in food safety and quality • Agricultural market research and development • Revenue collection and tax compliance • Inclusive agricultural financing, transformation, and development and environmental sustainability • Environmental protection, biodiversity conservation • Standards and certifications in food safety and quality	• Policy, extension services, farmer support, climate-resilient agriculture • Conservation tillage, sustainable land management • CSA enforcement, water regulations, land restoration, ecosystem management, grain and oilseeds farming • CSA certification, implementation of climate smart practices • Carbon tax, greenhouse gas reduction, renewable energy incentives • Farmer support, climate-smart technologies, international alignment, natural capital policies, green financing, conservation agriculture • CSA implementation, local support, land care, climate advisory services • CSA enforcement, water regulations, land restoration, ecosystem management, grain and oilseeds farming	• Climate Change Sector Plan for Agriculture (2021) • SABS SANS 241 (water quality standards), organic farming standards • National Climate Change Adaptation Strategy (2021) • CSA Market Access Reports and Agri-Trusts • Section 12L & 12B tax incentives • Green Finance Strategy (2020) • Western Cape SmartAgri Plan, Limpopo LandCare Projects • Transnet Climate Change Adaptation Strategy (2022)

Industry bodies	• South African National Seed Organisation (SANSOR) • Oilseeds Advisory Committee (OAC) • GrainSA • Maize Trust • South African Grain Information Service (SAGIS) • South African Oilseeds Producers' Organisation (SAOPA) - under CEOCO member institutions • Sunflower & Soybean Forum (SSF) - operates under the Oilseeds Advisory Committee • National Chamber of Milling (NCM) • South African Agricultural Processors Association (SAAPA) - indubitable under SAGIS • Protein Research Foundation (PRF) • African Farmers Association of South Africa (AFASA)	• Seed industry regulation • Grain and oilseeds trade and industry coordination • Farmer support and lobbying • Climate-resilient maize production, research funding, capacity building • Market information & transparency • Food security and sustainability • Market trends, data sharing, and policy and regulatory discussions • Industry advocacy, trade and policy engagements, and technical affairs • Industry representation and advocacy, local and international industry standards and compliance • Local protein production advocacy, research funding, technology transfer • Advocacy and representation, and farmer development	• Climate-resilient seeds, conservation agriculture, facilitation • Sustainable oilseed research, drought-resistant varieties, soil conservation • Conservation agriculture, farmer training, no-till, crop rotation, soil health • Climate-resilient maize, drought-tolerant varieties, smallholder support, GrainSA partnership • Grain production data, climate assessments, informed sustainable decisions • CSA adoption, reduced pesticide use, organic farming, water-efficient irrigation • Sustainable farming, climate-resilient sunflowers and soybeans, environmental mitigation • Eco-friendly milling, staple food fortification, sustainable agriculture alignment • Environmental footprint reduction, energy efficiency, sustainable sourcing, recycling • Sustainable protein crops, crop rotation, animal feed efficiency, import reduction • CSA promotion, climate education, risk mitigation, research collaboration	• SANSOR Seed Certification and Climate-Resilient Crops • OAC provides funding for research initiatives on drought tolerant crops • Grains SA engages in Farmer Innovation Programmes promoting not-till and cover crop techniques • Market and production data tools • Collaborates with PRF and OAC on sustainability-focused R&D • PRF-supported knowledge-sharing platform • Green production guidelines in milling sector • SAAPA Policy Engagements and Value Chain Research (internal & industry-specific) • Extensive climate-smart oilseed R&D • Involved in DALRRD-led CSA policy dialogues
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Farmers bodies		- Commercial and emerging farmers - Producer co-operations - Agri SA - Solidaridad Network - TechnoServe, USAID, and GIZ	- Production - Other agricultural services - Agricultural policy advocacy - Sustainable smallholder agriculture, CSA advocacy and implementation, and digital innovation - Smallholder farmer support, agribusiness development, CSA, and agricultural markets and trade	- Conservation agriculture (CA) implementation - Resource sharing, sustainable farming, collective investment, conservation technologies - CSA in livestock, sheep and goats, sustainable land use - Biochar, agroforestry, soil health, biodiversity, carbon sequestration, farmer education, CA, water management, soil testing, weather data, financial products - Investor partnerships, technical assistance, agribusiness viability, smallholder sourcing	- Farmers who have adopted no-till farming and or CA practices, some implementing through Grain SA, ARC, and ASSET research training programs amongst others. - Collective buying and use of equipment among farmers - supported by DALRRD and AgriSETA in CSA-aligned capacity-building programs “Climate Resilience” and “Sustainable Agriculture” projects - CSA in Southern Africa program, including RECLAIM sustainability programme - In partnership with Kellogg’s, TechnoServe launched a program in the Eastern Cape Province to train 400 smallholders – 70% of whom are women – on good agronomic practices and farming as a business - USAID works with SAFE to increase the competitiveness of the African food processing sector, benefiting over 1 000 food processors who source from more than 800 000 smallholder farmers. Commercial Agriculture for Smallholders and Agribusiness Technical Assistance Facility (CASA TAF)
Research entities		- Agricultural Research Council (ARC) - ASSET Research - Universities (e.g. University of Pretoria, Stellenbosch University, University of the Free State, University of KwaZulu-Natal, North-West University)	- Agricultural research including crop improvement - Research, training and capacity building, stakeholder engagement, and policy advocacy - Academic research on crops	- Research, climate-resilient crops, conservation tillage, sustainable farming systems - On-farm CA trials, minimal soil disturbance, organic cover, crop diversity, experiential learning, social innovation, CA mainstreaming - Educational programmes, sustainable agriculture	- ARC’s Climate-Smart Agriculture Research Program, and Agro-climate Technology Station at ARC-Infruitec - Conservation Agriculture Farmer Innovation Programme (CA FIP) - Research output on the impact of CA such as: CEEPA, and various agriscience and climate initiative faculties
Other	Input suppliers	- Seed Companies (e.g. Pannar, Pioneer, Agricol, Monsanto/Bayer) - Fertiliser and Chemical Suppliers (e.g. Omnia, Kynoch, Yara) - Machinery & Equipment Suppliers (e.g. John Deere, Agrico, Case IH) - Agro-processors and Crushers – Processors of maize, soybeans, and sunflower (e.g. Willowton Group, Tiger Brands, Bunge SA)	- Provides seed and other agrochemicals - Developing climate-smart inputs, enhancing soil health, promoting integrated pest management - Prioritise precision agriculture, water-efficient and low-emission technologies, and conservation tillage equipment - Emphasise sustainable sourcing, resource-efficient processing and CSA value chains	- Climate-resilient seeds, pest resistance - Agrochemical reduction, precision nutrient management - Efficient nutrient use, precision agriculture, water-saving irrigation, CA tools - Soil health, sustainable sourcing, sustainable practices	- Bayer’s Climate FieldView platform; Pioneer’s AQUAmax® drought-tolerant hybrids - Yara’s Climate Smart Agriculture Programme; Omnia’s Nutriology® and Green Revolution sustainable practices - John Deere’s Precision Ag suite; Agrico’s drip and micro-irrigation systems for water efficiency - Bunge’s Climate-Smart Supply Chain initiatives and Tiger Brands’ sustainable agriculture strategy

	Traders and processors	- Major Grain Traders – (Senwes, AFGRI, VKB, Tiger Brands, Pioneer Foods, DuPont Crop Protection, Syngenta South Africa, BASF South Africa, Sensako) - Commodity Exchanges – SAFEX (South African Futures Exchange)	- Storage, food processing, exports, marketing and market access - Market access, price stability, climate resilient agriculture, and future contracts and hedging	- Conservation agriculture, CSA advisory, sustainable grain premiums, storage, mechanisation, financing, CSA farmer support - Financial instruments, climate risk management, sustainable sourcing, CSA promotion	- Senwes Climate Resilience Programs via its agri-advisory platform, AFGRI's Agri Services and CSA-aligned Input Support programs, VKB's Producer Support Services integrating CSA techniques, Tiger Brands' Sustainable Agriculture Strategy, PepsiCo's Positive Agriculture initiative, Corteva's Climate Positive Agriculture program, Good Growth Plan – a Syngenta global CSA initiative, BASF's Sustainable Agriculture Solutions, and Sensako's Climate-Adapted Seed Breeding Programmes - SAFEX via JSE Commodities Derivatives Market offers hedging tools for farmers to manage volatility
	Exports and distributors	- Exporters and Brokers – Involved in global grain/oilseed trade (often work through ports like Durban and Cape Town) - Transporters and Logistics Firms	- Global trade - Distribution logistics	- International sustainability compliance, sustainable grain sourcing, GHG reduction, climate risk mitigation - Climate-smart exports, fuel-efficient transport, route optimization, supply chain decarbonisation	- Louis Dreyfus Sustainability Initiatives, Cargill Climate Commitment, Bunge's Climate-Smart Ag Strategy, and Transnet's Low-Carbon and Port Efficiency Programmes - Implementation of rail transport systems that lower emissions compared to road transport such as through Imperial's Environmental Strategy, Barloworld Smart Transport, and Unitrans Sustainability Roadmap
	Finance and insurance providers	- Land Bank - Agri-financing Divisions of Banks – Standard Bank, FNB, Absa Agribusiness, Nedbank Agribusiness - Agricultural Insurance Providers – Santam Agriculture, Hollard Agri, Mutual & Federal.	- Inclusive agricultural financing, transformation, and development, and environmental sustainability - Comprehensive agribusiness solutions, agricultural and digital innovation - Comprehensive and specialised agricultural insurance coverage, risk assessment and management, adaptivity and innovation	- CSA technology adoption, sustainable development alignment, natural capital risk policies, green financing, conservation agriculture - Sustainable finance, resource-efficient tech, farmer training, climate adaptation policy, sustainable lending - Precision agriculture, conservation practices, data-driven risk analysis, climate insurance, risk mitigation tools	- Green Finance Strategy (2020) - Standard Bank Sustainable Agriculture Finance, FNB Agribusiness Sustainability Focus, Absa's Green Agriculture Investment Programmes, and Nedbank's Climate-Smart Lending Initiatives - Hollard Agri Product Suite and CSA Alignment, and Old Mutual Insure AgriWeather Products

	Media	• Landbou • ReStory • RegenAg SA • GrainSA Magazine • ASSET Research • Food for Mzansi • Farmer's Weekly	• Knowledge dissemination, climate-resilient farming, farmer education • Regenerative agriculture, ecosystem restoration, climate resilience, inclusive rural development • Regenerative agriculture, soil health, carbon sequestration, biodiversity, farmer education • Knowledge dissemination, conservation agriculture, sustainable practices, policy advocacy • Research, training and capacity building, stakeholder engagement, and policy advocacy • Farmer stories, youth in agriculture, climate adaptation, agri-innovation • Conservation agriculture, policy analysis, drought mitigation, regenerative farming	• Climate-smart agriculture, water efficiency, regenerative agriculture, and carbon farming, expert insights, case studies, and innovations from across South Africa • Regenerative agriculture and land restoration, soil health, agroecology, inclusive value chains • Farmer training, consultancy, field support on regenerative practices, partnership with local and international stakeholders to promote climate-smart agriculture • Publishing educational content on minimum tillage, drought-tolerant crop varieties, cover cropping, climate risk management, and farmer-led innovations in climate-smart agriculture • Conservation agriculture practices through on-farm trials with local farmers, emphasizing minimal soil disturbance, organic soil cover, crop diversity, experiential learning, and social innovation to promote widespread adoption • CSA success stories, climate-resilient techniques, agricultural innovation dissemination, CSA farmer training, climate-smart agriculture webinars • CSA best practices, conservation tillage, efficient irrigation, government CSA policies, climate adaptation insights, expert commentary, CSA thought leadership	• Various collaborations and publications on regenerative conservation agriculture • Collaborations on regenerative programs with Mahkathini Development Foundation, MilkSA and others • Various regenerative grazing and farming days or farm tours • Publishes articles on minimum tillage, drought-resistant varieties, cover cropping, climate risk management, and farmer-led CSA innovations. Supports education and awareness among grain producers • Project resources and publications https://assetresearch.org.za/conservation-agriculture/ • Highlighted young farmers using climate-smart hydroponics and renewable energy. • Published detailed guides on climate-resilient crops, carbon farming, and sustainable livestock management
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A8.2 Livestock

	Main role players	Key focus areas	Climate smart activities	Examples
All livestock				
Government bodies	- Department of Rural Development & Land Reform (DALRRD) - Department of Agriculture, Forestry and Fisheries (DAFF) - National Agricultural Marketing Council (NAMC) - Meat Safety Act (MSA) - South African Meat Industry Company (SAMIC) - Provincial Departments of Agriculture - South African Veterinary Council (SAVC) - South African Bureau of Standards (SABS) - Department of Trade, Industry and Competition (DTIC)	- Rural development, land reform - Livestock policy, sustainable agriculture, food security - Agricultural market research and development - Meat safety and beef quality assurance - Meat industry standards and advocacy - Environmental protection, biodiversity conservation - Animal and public health safeguarding, and regulation and accreditation. - Dairy safety standards, quality assurance - Competition policy and economic inclusion, trade facilitation and export promotion, and industrial policy.	- Sustainable grazing support, CSA in rural livestock - CSA adoption, livestock management - Climate-resilient beef markets, regenerative grazing, sustainable beef incentives - CSA in beef, low-emission production, safety standards compliance - CSA integration, sustainable beef education - CSA implementation, local support, land care, climate advisory services - Climate-smart livestock nutrition, soil fertility, water conservation - CSA standards in national dairy systems, eco-friendly and ethical production - Low-carbon economy, green industries, renewable energy, climate collaboration	- Climate Change Sector Plan for Agriculture (2021) - Draft Climate Change Adaptation and Mitigation Plan for Agriculture - DALRRD CSA Plan - Hygiene and meat safety frameworks support CSA by improving resource efficiency - Red Meat Classification System - Western Cape Climate Smart Agriculture Project, Eastern Cape Red Meat Development - Veterinary Public Health Standards & One Health Framework - Agricultural Industry Trusts & Transformation Review - Green Economy Strategy, Agro-Processing Support Scheme (APSS), and Black Industrialists Programme with CSA-compatible incentives - DTIC Programmes
Industry bodies	- Agricultural Business Chamber (ABC) - Agri SA - African Farmers' Association of South Africa (AFASA) - AgriSETA	- Agricultural business advocacy - Policy advocacy, disaster relief, and sustainability and transformation. - Advocacy and representation, and farmer development. - Skills development, research and sector planning.	- CSA adoption, sustainable grazing, integrated livestock management - Sustainable farming, dairy-relevant practices, water and waste management - Sustainable agriculture, climate education, risk mitigation, research collaboration - CSA training, capacity building, environmental stewardship, conservation, adaptation, CSA research	- Policy advocacy for climate finance in agriculture "Climate Resilience" and "Sustainable Agriculture" projects - Involved in DALRRD-led CSA policy dialogues - Sustainable farming techniques such as conservation agriculture, water use efficiency, and agroecology through Agri-Edu Symposium on CSA

Research entities		• Agricultural Research Council (ARC) – AP and OVR • Universities (e.g. University of Pretoria, Stellenbosch University, University of the Free State, North-West University, University of Limpopo, University of Fort Hare)	• Livestock research, sustainable farming • Academic research on livestock	• CSA in beef, rotational grazing, pasture management, animal health • Sustainable beef research, CSA principles, agroecology, feed efficiency	• CSA Livestock Technologies and Improved Breeds, and Climate Change & Vector-Borne Diseases Research • CSA Hub at the Faculty of Natural and Agricultural Sciences UP Climate Resilience Research, Conservation Agriculture Project SU Soil Science & CSA, Global Change & Sustainability Research Institute UFS, CSA Research in North West Province NWU Faculty of Natural and Agricultural Sciences, Smallholder Climate-Smart Practices Projects UL Research & Innovation, and CSA Capacity Building in Eastern Cape UFH Agricultural Research
Other	Exports and distributors	• Exporters • Retail and wholesalers - Shoprite, Pick n Pay, Spar, Woolworths, Checkers	• Global distribution of fresh fruits and vegetables, marketing and exports • Food security, food waste reduction, sustainable sourcing and supply chain	• CSA farming, water conservation, precision agriculture, eco-packaging, energy efficiency • Food waste repurposing, vertical farming, water risk management, biological farming, community gardening, sustainable agriculture	• Capespan Sustainability Strategy, Core Fruit Sustainability Commitment, Sustainability & Environment Report Dutoit, Supplier Development & Environmental Goals Stems Fruit, SAFE Sustainability Overview, Ethical Trading & Sustainable Sourcing Info Colors Fruit, Distell ESG Strategy, KWV Environmental Policy, Backs initiatives with WIETA and WWF-SA • Shoprite collaboration with Seriti Institute to empower local farmers and livelihoods. Small scale farming initiatives by PnP in the Eastern Cape. Spar growing the good initiative through its famer programme, and Woolworths farming for the future campaign
	Finance and insurance providers	• Land Bank • Agri-financing Divisions of Banks – Standard Bank, FNB, Absa Agribusiness, Nedbank Agribusiness • Agricultural Insurance Providers – Santam Agriculture, Hollard Agri, Mutual & Federal	• Inclusive agricultural financing, transformation, and development, and environmental sustainability • Comprehensive agribusiness solutions, agricultural and digital innovation • Comprehensive and specialised agricultural insurance coverage, risk assessment and management, adaptivity and innovation	• CSA technology adoption, sustainable development alignment, natural capital risk policies, green financing, conservation agriculture • Sustainable finance, resource-efficient tech, farmer training, climate adaptation policy, sustainable lending • Precision agriculture, conservation practices, data-driven risk analysis, climate insurance, risk mitigation tools	• Green Finance Strategy (2020) • Standard Bank Sustainable Agriculture Finance, FNB Agribusiness Sustainability Focus, Absa's Green Agriculture Investment Programs, and Nedbank's Climate-Smart Lending Initiatives • Hollard Agri Product Suite and CSA Alignment, and Old Mutual Insure AgriWeather Products

	Media	• Landbou • ReStory • RegenAg SA • Grain SA Magezine • ASSET Research • Food for Mzansi • Farmer's Weekly	• Knowledge dissemination, climate-resilient farming, farmer education • Regenerative agriculture, ecosystem restoration, climate resilience, inclusive rural development • Regenerative agriculture, soil health, carbon sequestration, biodiversity, farmer education • Knowledge dissemination, conservation agriculture, sustainable practices, policy advocacy • Research, training and capacity building, stakeholder engagement, and policy advocacy • Farmer stories, youth in agriculture, climate adaptation, agri-innovation • Conservation agriculture, policy analysis, drought mitigation, regenerative farming	• Climate-smart agriculture, water efficiency, regenerative agriculture, and carbon farming, expert insights, case studies, and innovations from across South Africa • Regenerative agriculture and land restoration, soil health, agroecology, inclusive value chains • Farmer training, consultancy, field support on regenerative practices, partnership with local and international stakeholders to promote climate-smart agriculture • Publishing educational content on minimum tillage, drought-tolerant crop varieties, cover cropping, climate risk management, and farmer-led innovations in climate-smart agriculture • Conservation agriculture practices through on-farm trials with local farmers, emphasizing minimal soil disturbance, organic soil cover, crop diversity, experiential learning, and social innovation to promote widespread adoption • CSA success stories, climate-resilient techniques, agricultural innovation dissemination, CSA farmer training, climate-smart agriculture webinars • CSA best practices, conservation tillage, efficient irrigation, government CSA policies, climate adaptation insights, expert commentary, CSA thought leadership	• Various collaborations and publications on regenerative conservation agriculture • Collaborations on regenerative programs with Mahkathini Development Foundation, MilkSA and others • Various regenerative grazing and farming days or farm tours • Publishes articles on minimum tillage, drought-resistant varieties, cover cropping, climate risk management, and farmer-led CSA innovations. Supports education and awareness among grain producers • Project resources and publications https://assetresearch.org.za/conservation-agriculture/ • Highlighted young farmers using climate-smart hydroponics and renewable energy • Published detailed guides on climate-resilient crops, carbon farming, and sustainable livestock management
Beef (in addition to above)					
Government bodies		• Meat Safety Act (MSA) - regulated under the DALRRD • South African Meat Industry Company (SAMIC)	• Meat safety and beef quality assurance • Meat industry standards and advocacy	• CSA in beef, low-emission production, safety standards compliance • CSA integration, sustainable beef education	• Hygiene and meat safety frameworks support CSA by improving resource efficiency • Red Meat Classification System

Industry bodies	• South African Meat Processors Association • Red Meat Producers Organisation (RMPO) • National Emergent Red Meat Producers' Organisation (NERPO) • Red Meat Industry Services (RMIS) • National Animal Health Forum (NAHF) • South African Meat Industry Company (SAMIC) • South African Feedlot Association (SAFA)	• Meat processing, value chain development, and beef quality control • Red meat sector sustainability • Commercialisation of emerging farmers, policy advocacy, infrastructure development, and capacity building and training • Industry policy formulation and regulatory compliance • Policy advocacy, information dissemination, and stakeholder engagement • Regulatory compliance, training and capacity building • Advocacy and representation, and research and development	• CSA-based meat sourcing, organic feed, sustainable grazing • Regenerative grazing, pasture health, emissions reduction • Fodder banks, water storage, sustainable land use, community adaptation, integrated crop-livestock systems • Sustainable practices, climate collaboration, resilience support • Climate-related disease surveillance, resilient livestock systems, CSA-aligned collaboration • Sustainable farming, traceability, ethical practices, stakeholder collaboration • Feed management, manure systems, water conservation, feedlot emissions regulation	• TLU SA on soil and water health and its role of technology in sustainable agriculture • Climate Resilience Training for Farmers • NERPO Livestock Development Projects • Sustainable Meat Production Guidelines • Livestock Climate Risk & Biosecurity Forums • Red Meat Sustainability Audits including the Karoo Meat of Origin program - encourages rotation grazing, low stocking densities, and natural veld preservation for environmental sustainability • SAFA Green Feedlot Practices
Farmers bodies	• Beef Farmer Cooperatives • South African Livestock Farmers • National Beef Producers Organisation (NBPO) • Solidaridad Network, WWF-SA, and Conservation South Africa • Bonsmara Cattle Breeders' Society, Nguni Cattle Breeders' Society, Brahman Breeders' Society	• Livestock production, sustainable farming • Beef production and sustainability • Beef sector advocacy, producer support • Promote climate-smart and regenerative agriculture practices • Climate-resilient cattle genetics, indigenous and adapted breeds, and sustainable grazing systems	• CSA in beef, rotational grazing, organic manure use • Rotational grazing, sustainable pasture management, beef quality, land degradation reduction • CSA methods, grazing rotation, sustainable feed practices • CSA models, climate adaptation, carbon footprint tools, regenerative agriculture (RA), GHG reduction, climate info systems	• Adoption of CSA by communal livestock farmers • Climate-smart livestock nutrition in semi-arid regions • Sustainability & Value Chain Meetings • RECLAIM Sustainability! Programme and Sustainable Agriculture Programme • Selection Signatures in Bonsmara Cattle and Using Brahman Cattle for Climate Smart Ranching
Research entities	• ASSET Research	• Research, training and capacity building, stakeholder engagement, and policy advocacy	• On-farm CA trials, minimal soil disturbance, organic cover, crop diversity, experiential learning, social innovation	• Conservation Agriculture Farmer Innovation Programme (CA FIP)

Other	Input suppliers	- Companies such as: Agrimark (Pty) Ltd, Impextraco (Pty) Ltd, AfriAgri (Omnia), Pannar Seed - Animal Feed Suppliers – E.g. Meadow Feeds, Nutri Feeds, Voermol - Veterinary Pharmacies and Animal Health Suppliers – MSD Animal Health, Zoetis, Virbac - Genetic Services and AI Providers – Taurus, Genex, ARC, individual breed societies	- Agricultural inputs, animal feed - Feed and nutrition services for livestock - Fertilisers and livestock nutrition - Seed production, pasture management	- CSA-aligned animal feed, cattle health, land sustainability - Low-methane feed, reduced environmental impact of beef production - CSA products, natural fertilisers, regenerative livestock feed - Seeds for rotational grazing, regenerative pastures, healthy grazing systems	- CSA input supply partnerships with farmers Agrimark, Sustainable Feed Additive Programs Impextraco Globa, Nutriology® CSA Strategy Omnia Nutriology, and Pannar Climate Smart Seed Portfolio Pannar Seed - Environmental Sustainability Strategy Meadow Feeds, Green Feed Manufacturing Initiatives Nutri Feeds, and Voermol Ruminant Efficiency Programs Voermol - Weather-Linked Disease Mitigation Tools MSD SA, Precision Animal Health Tools Zoetis South Africa, and One Health Approach Virbac SA - Climate Resilient Breeding Services Taurus AI, GENEX Climate-Adapted Genetics Program Genex Global, Climate-Adapted Livestock Breeding Programs ARC, and Nguni and Bonsmara Resilience Projects
	Traders and processors	- The South African Meat Processors Association (SAMPa) - TLU SA (The Transvaal Agricultural Union) - Companies such as: ABP Food Group, Beefmaster Group, Olam Group, Karan Beef, Sparta Beef, Beefmaster, Morgan Beef	- Meat processing, value chain development, and beef quality control - Beef processing, logistics - Sustainable beef production, climate-resilient supply chains, regenerative grazing, traceability, and export standard	- CSA-based meat sourcing, organic feed, sustainable grazing - CSA techniques, reduced feedlot use, optimized land use - Sustainable beef processing, waste reduction, beef value chain	- TLU SA on soil and water health and its role of technology in sustainable agriculture - Olam Agri – Climate & Landscapes
Dairy (in addition to above)					
Government bodies		- South African Milk Producers Organisation (SAMPRO) - Milk SA	- Dairy producer advocacy, sectoral support - Research and development, and industry collaboration	- Efficient feed and water use, CSA in dairy, environmental sustainability - Watercourse buffer zones, runoff filtration, erosion control, climate-resilient farming	- Linked to Milk SA R&D programmes under sustainability - Sustainable Dairy Production Manual, climate focus through Milk SA's Transformation Projects

Industry bodies	• South African Dairy Association (SADA) • Milk Producers Organisation (MPO) • Agricultural Research Council (ARC) - Dairy Research • Dairy Standard Agency (DSA) • South African Milk Processors Organisation (SAMPRO) • National Milk Recording and Improvement Scheme (NMRIS)	• Dairy industry advocacy, research, and marketing • Dairy producer support, policy advocacy • Dairy research, breed improvement, nutrition • Regulatory compliance, product quality and safety, and animal welfare • Regulatory compliance, industry support and consumer education • National data integration, and milk performance recordings	• Sustainable dairy, water-saving technologies, sustainable feed • CSA in dairy, rotational grazing, pest management, low-carbon feed • Sustainable breeding, animal welfare, regenerative grazing • Water efficiency, sustainability guidelines, Milk SA collaboration • Waste and water recycling, water management partnerships, sustainable packaging, energy efficiency • Feed efficiency, environmental footprint reduction, data-driven decisions, animal health	• SA promotion via SADA Dairy Industry Sustainability Vision • MPO Climate Smart Dairying module under farmer development • Climate-oriented research at ARC-Animal Production • Code of Practice for Dairy Processors • Linked to Milk SA R&D programmes under sustainability • Operated by ARC & Milk SA under sustainable breeding programmes
Farmers bodies	• South African Dairy Farmers • South African Farmers Development Association (SAFDA) • Grain SA's Farmer Development Programme • Solidaridad Network, Heifer International South Africa, WWF-SA, GIZ	• Dairy production, sustainability • Dairy farming, land access, financial support • Climate-smart farming training, conservation agriculture, smallholder support, and sustainable grain production • Promote climate-smart and regenerative agriculture practices	• CSA dairy, rotational grazing, manure management, water-efficient systems • Sustainable dairy training, organic production, rotational grazing • (Duplicate) CSA dairy, water efficiency, sustainable feed, organic methods • CSA models, climate adaptation, carbon tools, regenerative agriculture, GHG reduction, climate knowledge systems	• Many supported via Milk SA & ARC Dairy CSA Training • Partners with GIZ & DALRRD for CSA in emerging sectors • Farmer Development Programme including livestock • Southern Africa CSA Programme (Solidaridad), Smallholder Climate Resilience Projects (Heifer), Sustainable Dairy Partnerships (WWF-SA), and CSA in Livestock & Dairy – SA-German Climate Programme (GIZ)
Research entities	• ASSET Research	• Research, training and capacity building, stakeholder engagement, and policy advocacy	• On-farm CA trials, minimal soil disturbance, organic cover, crop diversity, experiential learning, social innovation	• Conservation Agriculture Farmer Innovation Programme (CA FIP)

Other	Input suppliers	• Dairy Feed Suppliers – Meadow Feeds, Voermol, Nutri Feeds, AfriAgri (Omnia), Vuna Fertilizers, and Cargill South Africa • Dairy Equipment Suppliers – DeLaval, GEA, Afimilk, Westfalia – Provide milking systems, cooling tanks, etc. • Veterinary and Animal Health Companies – MSD Animal Health, Zoetis, Virbac • Artificial Insemination & Genetics Companies – Taurus, Semex, World Wide Sires, CRV Xseed	• Dairy feed and nutritional solutions • Fertilisers, feed, and farm inputs for dairy production • Enhance animal health and welfare • Provides access to affordable AI solutions for farmers, and advancing reproductive technologies	• Organic feed, low-carbon options, sustainable dairy systems • CSA dairy feed and fertilisers, soil health, animal nutrition • Environmental policy, GHG reduction, renewable energy, water and waste management • Genetic programs, disease resistance, animal longevity, reduced environmental footprint	• Supports low-carbon livestock production Meadow Feeds, Weather-Linked Disease Mitigation Tools MSD SA, provides technical support for sustainable beef and dairy systems Voermol, participates in sustainable livestock partnerships Nutri Feed, Omnia Nutriology climate-smart nutrient management, Focuses on organic and biologically enhanced fertilizers Vuna, Precision Animal Health Tools Zoetis South Africa, and One Health Approach Virbac SA • DeLaval Sustainability Strategy: GEA Sustainable Dairy Technologies, Afimilk Smart Farm Solutions, and Works toward energy efficiency and CSA compliance • Weather-Linked Disease Mitigation Tools MSD SA, Precision Animal Health Tools Zoetis South Africa, and One Health Approach Virbac SA • Climate Resilient Breeding Services Taurus AI, GSemex Immunity+™ Genetics Program for healthier, climate-resilient livestock, World Wide Sires South Africa promotes CSA through their breeding tools, and CRV's Fertility & Efficiency Traits tools aimed at climate adaptation
	Traders and processors	• South African Milk Processors' Organisation (SAMPRO) • Milk Producers Organisation (MPO) • Companies such as: Parmalat (Lactalis SA), Clover, Woodlands Dairy, Fair Cape Dairies, Orange Grove	• Energy efficiency, sustainable dairy processing, water management • Sustainable dairy farming, water use efficiency, feed optimisation, carbon footprint awareness • Dairy processing, consumer products	• Energy-saving technologies, sustainable milk processing guidelines, and waste reduction systems • climate-smart training, efficient irrigation and manure management, renewable energy • Energy-efficient dairy processing, low-carbon milk products	• Encouraged eco-friendly dairy processing and collaborated with other stakeholders • Provides extension services and training to dairy farmers to implement climate-adaptive practices • Participates in WWF-SA dairy water stewardship projects, Reports under Clover Sustainability Reports on CSA-aligned goals, Runs the "Green Factory" initiative, Fair Cape EcoFresh and carbon-neutral certification, and recognized for sustainability improvements in processing

Sheep and goats (in addition to the above)				
Government bodies	• South African Veterinary Association (SAVA)	• Animal health and welfare	• CSA-aligned veterinary practices, reduced chemicals, holistic livestock health	• Contributes to One Health and climate-adaptive livestock health frameworks
Industry bodies	• National Wool Growers' Association (NWGA) • Eastern Cape Rural Development Agency (ECRDA) • South African Mohair Growers' Association (SAMGA) • Red Meat Producers' Organisation (RPO) • National Emergent Red Meat Producers' Organisation (NERPO)	• Wool production, farmer support • Rural development and financing, land reform and management, and research and innovation • Animal health and welfare, sustainable farming practices, and producer advocacy and representation • Producer advocacy and representation, animal health, market development and trade • Commercialisation of emerging farmers, policy advocacy, infrastructure development, and capacity building and training	• Regenerative grazing, wool production, animal welfare • Sustainable agriculture practices, productivity, natural resources, CSA alignment • Regenerative farming, mohair, water efficiency, sustainable land management, carbon footprint, traceability • Grazing management, overgrazing prevention, soil health, pasture productivity, methane reduction, manure management, resilience • Fodder banks, water storage, sustainable land management, community-based adaptation, integrated crop-livestock systems	• Communal Wool Farmer Development Programme (supports 24,000+ farmers) • Provides financial support and services to rural enterprises, facilitating access to capital for agricultural and related activities through the Eastern Cape Rural Finance Corporation (ECRFC) • Supports the implementation of standards like the Responsible Mohair Standard (RMS), ensuring that mohair is produced ethically, with attention to animal welfare and environmental sustainability • Participates in Red Meat Industry Strategy Plan aligned with CSA • CSA featured in land degradation and resilience extension programs in collaboration with DALRRD & NWGA

Farmers bodies		• South African Sheep and Goat Farmers • National Wool Growers' Association (NWGA) • Sheep and Goat Farmers Co-operative • Karakul Breeders' Society and Boer Goat Breeders' Society, Savanna Goat Society, Kalahari Red Goat Club • Solidaridad Network, Heifer International South Africa, WWF-SA, GIZ, FAO • Mohair Empowerment Trust	• Sheep and goat production, sustainable farming • Sustainable wool production, veld (rangeland) management, soil conservation, climate resilience • Cooperative support, market access for sheep and goat farmers • Support breeders, and establish and maintain breed standards • Empowering smallholder farmers, advancing CSA and RA practices, and enhancing food security • Supports emerging farmers, and industry integration	• CSA, water-efficient farming, rotational grazing, crop-livestock systems, soil improvement, land use • Promotes sustainable grazing systems, trains farmers in regenerative practices, supports sheep breed adaptation for climate resilience, and erosion control • Sustainable grazing, feed management, land restoration, CSA practices • Sustainable grazing, overgrazing prevention, land degradation, research, sustainable feeding, pasture management, low-input farming • CSA projects (Kitovu, LI-SAF, RECLAIM), low-cost farming, sustainable farming methods, agricultural mechanisation • Rotational grazing, sustainable land management, international standards, solar panels, efficient irrigation, environmental impact	• Supported through NWGA & SGFASA initiatives for veld improvement & drought adaptation • Implemented farmer support and training programs focused on rangeland rehabilitation, rotational grazing, and erosion control techniques in the Eastern Cape • Regional cooperative models linked to NWGA extension support and provincial training • Participates in climate-resilient livestock development via breed improvement programs, and Breed societies support CSA-compatible livestock genetics and veld-friendly practices • Southern Africa CSA Programme (Solidaridad), Smallholder Climate Resilience Projects (Heifer), Sustainable Dairy Partnerships (WWF-SA), and CSA in Livestock & Dairy – SA-German Climate Programme (GIZ) • Linked to SAMGA and empowerment farms under Mohair Trust CSA training
Other	Input suppliers	• Animal Health Companies - Merck Animal Health, MSD Animal Health, Zoetis, Virbac • Feed and Mineral Supplement Suppliers – Voermol, Meadow Feeds, Nutri Feeds • Genetic and Breeding Services – ARC, private breeders, and AI services	• Animal health products, sheep and goat disease management • Animal feed, nutrition for livestock • Genetic solutions, and reproductive management, and technologies	• Animal health, climate-resilient farming, disease reduction, nutrition, management practices • Sustainable feed, CSA goals, carbon footprint reduction, feed efficiency • Sustainable livestock production, resilience, trait-enhancing breeding programmes	• Weather-Linked Disease Mitigation Tools MSD SA, Precision Animal Health Tools Zoetis South Africa, and One Health Approach Virbac SA • CSA-focused formulation in rangeland supplementation, Nutritional Services and feed management plans under sustainability focus, and Supports CSA through customised feeding solutions for improved resilience • Climate Smart Agriculture Research & Innovation Programme; ARC-Animal Production & ARC-VOPI workstreams, ForFarmers Precision Livestock Nutrition Services – climate adaptation-focused, Breed societies promote CSA traits in herd improvement initiatives, and CRV Climate Efficiency Index and World Wide Sires Sustainability Breeding Goals

	Traders and processors	• Cape Wools SA • Mohair South Africa • BKB, OVK, CMW, Schoeman Boerdery	• Research and development, sustainable wool production, market information and access • Sustainable and climate resilient mohair production, traceability, and certification • Wool and Mohair brokerage, grain and agri-retail, and livestock and auctions	• Breed heat stress, regenerative agriculture, rotational grazing, rangeland restoration, traceability, transparency database • Regenerative grazing, soil health, animal welfare, Sustainable Mohair Production Guidelines, WWF-SA, Textile Exchange • Contamination-Free Wool	• RWS Certification in South Africa, in collaboration with IWTO and WWF-SA • Sustainable Mohair Production Guidelines, Responsible Mohair Standard (RMS) • RWS & RMS Certified Broker, supports regenerative grazing through value chain services (BKB Sustainability), Works with Cape Wools SA and NWGA on sustainable livestock development (OVK), Works with Mohair SA and producers under Sustainable Mohair Guideline (CMW), and Schoeman Frams that are known for adopting regenerative CSA practices in potato and beef production
Poultry (in addition to the above)					
Industry bodies		• South African Poultry Association (SAPA) • South African Layer Breeders Association (SALBA) – operates under SAPA • Poultry Disease Management Association (PDMA) • South African Feedlot Association (SAFA)	• Poultry industry advocacy, market access • Egg production, sustainable poultry breeding • Poultry disease management and biosecurity • Poultry feedlot management, sustainability	• Sustainable poultry, feed efficiency, water conservation, waste reduction • CSA in layers, feed-to-egg ratio optimization, sustainable systems • CSA disease prevention, eco-friendly pest and disease control • Sustainable feedlots, low-impact poultry feed, carbon footprint reduction	• Supports the Poultry Master Plan, which includes elements of sustainability and biosecurity • Works under SAPA's umbrella—encourages responsible genetics and low-carbon egg production • Leads national surveillance and early warning systems for poultry diseases • SAFA Green Feedlot Practices
Farmers bodies		• South African Broiler Producers' Organisation (SABPO) – operates under SAPA • South African Egg Producer Organisation (SAEPO) – operates under SAPA	• Broiler production, sustainability • Egg production, animal welfare	• Sustainable broiler farming, feed efficiency, water conservation, waste management • CSA in egg production, energy use reduction, waste management	• Collaborates with SAPA and WWF-SA on sustainable poultry production; aligned with the Poultry Master Plan • Participated in SAPA's environmental stewardship initiatives and knowledge-sharing with animal welfare and sustainability groups
Other	Input suppliers	• Agri-Africa (Agricultural Input Suppliers & Exporters) • Feed Manufacturers: Astral Foods (Meadow Feeds), RCL Foods (EPOL), Nutri Feeds, Nova Feeds, Cargill South Africa • Genetics and Hatcheries: Rainbow, Cobb SA, Ross Breeders SA, Hy-Line SA (layers) • Veterinary and Pharmaceutical Companies: Zoetis, MSD Animal Health, Elanco, Bayer Animal Health • Equipment Suppliers: Munters, SKOV, Big Dutchman, etc.	• Poultry feed, vaccines, health products • Poultry feed, animal health products • Poultry health, disease prevention • Fertilisers and livestock nutrition • Advanced ventilation solutions, climate control solutions, and data driven management	• SA-friendly inputs, waste reduction, sustainable feed, poultry health • Efficient feed conversion, reduced impact, integrated poultry-crop systems • CSA-supportive vaccines, reduced antibiotic use, disease resilience • Natural fertilizers, regenerative livestock feed, veterinary care, sustainable animal agriculture • Energy-efficient tech, optimised energy use, lower livestock environmental footprint	• Promotes sustainable agricultural inputs across Africa • Cargill and Meadow Feeds implement sustainable poultry feed programmes • Cobb-Vantress SA promotes climate-resilient poultry genetics • Through MAHABA, Elanco works to reduce tick-borne diseases, improving animal health and productivity in Sub-Saharan Africa. Zoetis's poultry health solutions address heat stress and disease risk • Big Dutchman and Munters deliver CSA solutions like precision climate control

	Traders and processors	• Poultry Integrators: Astral Foods, RCL Foods (Rainbow Chicken), Country Bird Holdings, Sovereign Foods, Daybreak Farms, Tydstroom • Egg Producers: Nulaid (Quantum Foods)	• Poultry processing, consumer products • Poultry processing, market access	• CSA processing practices, waste reduction, energy efficiency, sustainable poultry sourcing • Sustainable poultry production, energy-efficient processing, responsible sourcing	• Sustainability reports highlight carbon reduction and resource-use optimization (Astral Foods ESG), RCL's "Sustainable Business Drive" and water reuse programs (RCL ESG), Integrated supply chain improvements mentioned in CBH operations, Sovereign is part of broader industry environmental compliance, Daybreak farms have Corporate environmental reports mention CSA-aligned practices. • Quantum Foods' sustainability reports outline CSA actions
	Exports and distributors	• Fast food chains: KFC, Chicken Licken, Nando's – Major poultry meat consumers	• Local sourcing	• Carbon reduction	• KFC's global ESG & sustainability targets, "Recipe for Good" initiative, Nando's "Sustainability" framework and Net Zero 2030 commitment, while Chicken Licken Indirect involvement via suppliers; no formal CSA reporting
Pigs (in addition to the above)					
Industry bodies		• South African Pork Producers' Organisation (SAPPO) • Animal Feed Manufacturers Association (AFMA) • National Emergent Red Meat Producers' Organisation (NERPO)	• Pork production, industry advocacy • Sustainable animal nutrition, feed efficiency, environmental impact reduction, circular economy • Animal feed manufacturing and standards • Commercialisation of emerging farmers, policy advocacy, infrastructure development, and capacity building and training	• Climate-smart pork production, feed efficiency, waste reduction, carbon footprint, pig farming • Promotes sustainable feed formulations, supports R&D on low-carbon feed additives, and encourages waste-to-feed innovations to reduce emissions • Sustainable feed, feed efficiency, environmental impact, pig farming • Fodder banks, water storage, sustainable land use, community adaptation, integrated crop-livestock systems	• SAPPO Sustainability Strategy & Farmer Support & Development Initiatives • Participation in policy dialogue and One Health framework with ARC and DAFF • Supports research and member initiatives • NERPO Livestock Development Projects

Farmers bodies		- South African Pork Producers' Organisation (SAPPO) - Heifer International, Solidaridad Network, GIZ, FAO	- Pork production, industry advocacy - Economic development and empowerment, advancing CSA and RA practices, and enhancing food security	- Climate-smart pork production, feed efficiency, waste reduction, carbon footprint, pig farming - CSA projects (Kitovu, LI-SAF, RECLAIM), low-cost farming, sustainable farming methods, agricultural mechanisation	- SAPPO Sustainability Strategy & Farmer Support & Development Initiatives - Smallholder livestock development projects; has collaborated in CSA-aligned projects in livestock (Heifer SA), Livestock production transformation projects in southern Africa, including piggery support initiatives (Solidaridad), GIZ's Inclusive and Climate-Smart Livestock Value Chains in South Africa program, and FAO CSA Frameworks in Southern Africa and Livestock Environmental Assessment and Performance (LEAP)
Other	Input suppliers	- Feed Suppliers: Agri-firm, Meadow Feeds, EPOL (RCL Foods), Nutri Feeds, Nova Feeds, Cargill South Africa - Genetics and AI Providers: PIC South Africa, DanBred SA, Topigs Norsvin - Veterinary and Pharmaceutical Companies: Zoetis, Bayer Animal Health, MSD Animal Health, Elanco, Virbac	- Pig feed, animal health products - Pig health, disease prevention - Pig feed, farm inputs	- Sustainable feed, CSA, feed-to-pig conversion, carbon footprint reduction, pig farming - CSA, disease prevention, antibiotic reduction, sustainable farming, resilience - CSA-friendly feeds, pig health, environmental impact, methane reduction, efficient feed use	- Involved in sustainable agriculture across feed chains (Agri-firm SA), Responsible Animal Feeding programs – part of Astral's sustainability strategy, (Astral), RCL Foods Sustainability Strategy 2025, (RCL Foods), Aligned to climate-resilient feed formulations. (Nutri Feeds), Uses environmental management plans in manufacturing, and Cargill Animal Nutrition CSA practices globally, (Cargill) - Offers high-efficiency breeding stock reducing emissions per kg meat (PIC SA), DanBred sustainability strategy includes CSA breeding focus (DanBred), and Part of "Sustainable Swine Breeding" initiative (Topigs Norsvin) - Zoetis Climate-Smart Livestock Health Programs (Zoetis), One Health and livestock productivity initiatives (Elanco), Connected Livestock Platform and climate resilience work (MSD AH), Global CSA-aligned programs like Sustainable Animal Productivity (Elanco), and Offers vaccines and supplements for sustainable pig health (Virbac)
	Traders and processors	Abattoirs and Processors – Eskort Ltd, Karan Beef, Winelands Pork, Lynca Meats, RCL Foods – Pork Division, TGR Poultry and Meat Processors	Pork processing, market distribution	CSA practices, pork processing, waste reduction, energy efficiency, sustainable production, sourcing	Eskort implements Sustainability & ESG principles in operations, Karan's sustainability and environmental stewardship practices, Publicly aligns to sustainable sourcing and environmental protocols, CSA-aligned waste management in pork processing chain (Lynca Meats), and RCL Foods Sustainability Strategy 2025 – focus on climate and water resilience

A8.3 Horticulture

	Main role players	Key focus areas	Climate smart activities	Examples
Government bodies	- Department of Agriculture, Forestry and Fisheries (DAFF) - South African Bureau of Standards (SABS) - Department of Agriculture, Land Reform and Rural Development (DALRRD) - Perishable Products Export Control Board (PPECB) - National Agricultural Marketing Council (NAMC) - Department of Trade, Industry and Competition (DTIC) - Department of Environmental Affairs (DEA) - South African Revenue Service (SARS) - Provincial Departments of Agriculture	- Horticulture & viticulture policy, pest & disease control - Standards and certifications in food safety and quality - Rural development, land reform - Quality assurance, product inspection, export certification, compliance, and cold chain management - Agricultural market research and development - Competition policy and economic inclusion, trade facilitation and export promotion, and industrial policy - Environmental protection, biodiversity conservation - Revenue collection and tax compliance	- CSA practices, water conservation, IPM, soil health - CSA certification, sustainable farming, energy-water-waste compliance - Sustainable grazing, CSA in rural livestock - Cold chain efficiency, climate-resilient supply chains, digital traceability tools - CSA beef markets, regenerative grazing, sustainable beef production - Low-carbon economy, green industries, renewable energy, climate collaboration - National Climate Change Adaptation Strategy (2021) - Offers Section 12L & 12B tax incentives that support CSA adoption - Western Cape: SmartAgri Plan, KZN & EC: climate-smart dairy extension services	- Draft Climate Change Adaptation and Mitigation Plan for Agriculture - DALRRD CSA Plan - SANS 14001 (Environmental Management Systems) and SANS 241 for water – standards relevant to CSA - Climate Change Sector Plan for Agriculture (2021) - Runs capacity-building programs on sustainable cold storage and export quality compliance. - Agricultural Industry Trusts & Transformation Review - Green Economy Strategy, Agro-Processing Support Scheme (APSS), and Black Industrialists Programme with CSA-compatible incentives - DTIC Programmes - Water regulation, land restoration, ecosystem management, CSA enforcement - Carbon tax, GHG reduction, renewable energy incentives - CSA extension, regional training, climate subsidies
Industry bodies	- Fresh Produce Exporters' Forum (FPEF) - Sundays Organic Growers Association (SOGA) - South African Organic Sector Organisation (SAOSO) - Southern African Society for Horticultural Sciences (SASHS)	- Fresh produce trade and export - Organic citrus farming, regenerative agriculture, soil health, farmer development - Organic farming, sustainability - Horticultural research, climate-resilient crop systems, sustainable production practices, academic exchange	- Sourcing, water-efficient irrigation, soil health, IPM, sustainable vegetable production - Supports smallholder organic citrus farmers in the Eastern Cape through regenerative farming practices, composting, and sustainable orchard management systems - CSA advocacy, organic farming, water efficiency, synthetic chemical reduction - Hosts conferences and publishes research promoting CSA in horticulture, including cultivar development, efficient irrigation, and reduced chemical inputs for sustainability	- Runs Ethical Trade and Environmental Awareness Programmes - Provides mentorship and support to smallholder citrus farmers to adopt organic-certified practices through its grower model - Leads CSA-aligned campaigns and capacity-building for organic growers - Facilitating scientific collaboration and knowledge dissemination

Farmers bodies		• AgriSETA • Solidaridad Network, WWF-SA, GIZ, FAO • Sundays Organic Growers Association (SOGA)	• Skills development, accreditation and quality assurance, and research and sector analysis • Promote climate-smart and regenerative agriculture practices • Organic citrus farming, regenerative agriculture, soil health, farmer development	• CSA training, environmental stewardship, adaptation, research support • CSA models, carbon tools, RA for food security, GHG reduction, knowledge systems • Supports smallholder organic citrus farmers in the Eastern Cape through regenerative farming practices, composting, and sustainable orchard management systems	• Offers accredited climate-smart farming skills programmes • Active in climate-smart supply chain pilots in the Western Cape - Solidaridad, Co-founded Conservation Champions program with WOSA/Vinpro - WWF-SA, Involved in CSA-GAP (Good Agricultural Practices) pilots - GIZ, and Provides climate-smart production guidelines and tools • Provides mentorship and support to smallholder citrus farmers to adopt organic-certified practices through its grower model
Research entities		• Agricultural Research Council (ARC) • Universities (University of Stellenbosch, University of Pretoria, University of Cape Town, UKZN, University of Limpopo, University of Free State, North-West University)	• Crop science, pest management, sustainable horticulture • Research, development, innovation, and knowledge transfer	• Water efficiency, pest-resistant crops, organic farming, reduced pesticide use • CSA in vineyards, water use, soil health, biodiversity, climate resilience, fruit yield, vegetable farming	• Climate Smart Agriculture & Conservation Horticulture Program, including tech transfer to farmers • Various faculties
Other	Input suppliers	• DuPont Crop Protection • Syngenta South Africa • BASF South Africa	• Crop protection products, pest management • Crop protection, seed genetics, and solutions • Crop protection, soil management, and nutrition	• Sustainable pest products, reduced chemical use, IPM • CSA solutions, reduced pesticide use, sustainable pest management • Environmental impact reduction, soil health, reduced chemical dependency	• Corteva Sustainable Solutions programme • Syngenta Sustainable Agriculture Plan and VitiSynth collaborations • BASF Agricultural Solutions – Viticulture Resilience
	Traders and processors	• SA wholesalers • SA retailers	• Fresh produce wholesale, distribution • Retail of fresh produce, sustainability	• CSA sourcing, reduced water use, minimal pesticides • Sustainable sourcing, organic farming, water efficiency	• Responsible Sourcing & Supplier Compliance • Farming for the Future & Sustainable Agriculture Sourcing Program Woolworths Holdings, Pick n Pay Sustainability Strategy & supplier partnerships Pick n Pay, Shoprite Group's Smallholder Farmer Support Programme Shoprite Holdings, and Sustainable Sourcing Policy with WWF and WIETA SPAR

	Exports and distributors	• Exporters – Capespan, Core Fruit, Dutoit Group, Stems Fruit, Fruit SA, SAFE, Colors Fruit, Distell, KWV, DGB, Kleine Zalze, Kanonkop, Meerlust, Nederburg, ZZ2, Green Farms, Halls, and Exporters of Fresh Produce South Africa (EFPSA) • Retailers and wholesalers - Woolworths, Shoprite, Pick n Pay, Spar, Checkers, Transfresh, Tru-Cape, Spar, Freshmark, OneFarm Share	• Global distribution of fresh fruits and vegetables, marketing and exports • Food security, food waste reduction, sustainable sourcing and supply chain	• CSA farming, water conservation, precision agriculture, eco-packaging, energy efficiency • Food waste reuse, vertical farming, water risk, biological farming, community gardening • CSA export sourcing, climate-resilient fruit and nuts, sustainable farms • Supplier engagement, CSA integration, IPM, eco-friendly packaging	• Capespan Sustainability Strategy, Core Fruit Sustainability Commitment, Sustainability & Environment Report Dutoit, Supplier Development & Environmental Goals Stems Fruit, SAFE Sustainability Overview, Ethical Trading & Sustainable Sourcing Info Colors Fruit, Distell ESG Strategy, KWV Environmental Policy, Backs initiatives with WIETA and WWF-SA • Farming for the Future & Sustainable Agriculture Sourcing Program Woolworths Holdings, Pick n Pay Sustainability Strategy & supplier partnerships Pick n Pay, Shoprite Group's Smallholder Farmer Support Programme Shoprite Holdings, and Sustainable Sourcing Policy with WWF and WIETA SPAR
	Media	• Landbou • ReStory • RegenAg SA • Grain SA Magezine • ASSET Research • Food for Mzansi • Farmer's Weekly	• Knowledge dissemination, climate-resilient farming, farmer education • Regenerative agriculture, ecosystem restoration, climate resilience, inclusive rural development • Regenerative agriculture, soil health, carbon sequestration, biodiversity, farmer education • Knowledge dissemination, conservation agriculture, sustainable practices, policy advocacy • Research, training and capacity building, stakeholder engagement, and policy advocacy • Farmer stories, youth in agriculture, climate adaptation, agri-innovation • Conservation agriculture, policy analysis, drought mitigation, regenerative farming	• Climate-smart agriculture, water efficiency, regenerative agriculture, and carbon farming, expert insights, case studies, and innovations from across South Africa • Regenerative agriculture and land restoration, soil health, agroecology, inclusive value chains • Farmer training, consultancy, field support on regenerative practices, partnership with local and international stakeholders to promote climate-smart agriculture • Publishing educational content on minimum tillage, drought-tolerant crop varieties, cover cropping, climate risk management, and farmer-led innovations in climate-smart agriculture • Conservation agriculture practices through on-farm trials with local farmers, emphasizing minimal soil disturbance, organic soil cover, crop diversity, experiential learning, and social innovation to promote widespread adoption • CSA success stories, climate-resilient techniques, agricultural innovation dissemination, CSA farmer training, climate-smart agriculture webinars • CSA best practices, conservation tillage, efficient irrigation, government CSA policies, climate adaptation insights, expert commentary, CSA thought leadership	• Various collaborations and publications on regenerative conservation agriculture • Collaborations on regenerative programs with Mahkathini Development Foundation, MilkSA and others • Various regenerative grazing and farming days or farm tours • Publishes articles on minimum tillage, drought-resistant varieties, cover cropping, climate risk management, and farmer-led CSA innovations. Supports education and awareness among grain producers • Project resources and publications https://assetresearch.org.za/conservation-agriculture/ • Highlighted young farmers using climate-smart hydroponics and renewable energy. • Published detailed guides on climate-resilient crops, carbon farming, and sustainable livestock management
Viticulture and table grapes (in addition to the above)					

Government bodies	• South African Wine and Brandy Company (SAWBC)	• Wine industry standards, export, policy advocacy	• Sustainable viticulture, organic farming, water conservation, biodynamics	• Supports Integrated Production of Wine (IPW) scheme – a key CSA programme
Industry bodies	• South African Table Grape Industry (SATI) • Vinpro • Wines of South Africa (WOSA) • South African Wine Industry Information & Systems (SAWIS) • Hortgro • SA Liquor Brand owners Association (SALBA)	• Wine industry funding, support, sustainability • Wine grape producers, sustainability, advocacy • Compliance with IPW standards, advocacy and representation for South African wines, labour relations in the wine industry • Wine certification, data collection, and information systems management • Market access and development, trade promotion and marketing, information and knowledge sharing • Regulatory advocacy, responsible consumption, and industry collaboration	• CSA table grapes, water reduction, IPM, soil health • SA in horticulture, pest management, efficient irrigation, soil health • Water conservation, carbon tracking, sustainable packaging, climate-resilient vineyards • Sustainability data for wine industry • Climate-resilient fruit R&D, resource efficiency, global sustainability standards • Energy efficiency, water conservation, sustainable packaging	• Supports CSA through Climate Resilience Strategy and training programmes • Offers CSA advisory services and SmartAgri partnerships • Leads Sustainable Wine South Africa (SWSA) platform • Supports CSA indirectly through wine value chain data management • Implements Post-Harvest Climate Response Plans and carbon foot printing • Supports CSA indirectly through member sustainability targets
Farmers bodies	• SATI Transformation Unit • Western Cape Wine and Agricultural Ethical Trade Association (WIETA)	• Table grape production, industry advocacy and transformation • Compliance, certification, stakeholder engagement and governance, and training and capacity building	• Emerging black grape farmers, climate-resilient irrigation, sustainability planning • Sustainable agriculture promotion	• Linked to SATI's Climate Resilience & Transformation Strategy • Implements ethical trade audits and CSA-linked compliance criteria
Research entities	• Wine Tech	• Viticulture research, wine production techniques	• Water research, drought-tolerant grapes, climate tools, carbon footprint tools, sustainable wine	• Wine Industry Innovation Program and Climate Change & Vineyard Sustainability Projects including participation in the confronting climate change (CCC) initiative
Fruits and nuts (in addition to the above)				

Industry bodies	• Fruit South Africa (Fruit SA) • South African Mango Growers Association (SAMGA) • SA Stone Fruit Producers Association (SASPA) • SA Apple and Pear Producers Association (SAAPPA) • South African Avocado Growers Association (SAAGA) • South African Litchi Growers Association (SALGA) • Citrus Growers Association of Southern Africa (CGA) and CGA Grower Development Company (CGA-GDC) • Hortgro • Subtropical Growers' Association (Subtrop) • Southern African Macadamia Growers' Association (SAMAC) • South African Pecan Nut Producers Association (SAPPA)	• Fruit export, market access, sustainability • Industry advocacy and representation, research and development, quality control and compliance, and training • Industry advocacy and representation, market development, shareholder engagement, and research and innovation • Trade facilitation, market access, industry representation, and training, research and development • Industry research, changing profitability and sustainability, market development and access and technical support and research • Industry representation and coordination, market development and access, and research and development • Sustainability and climate resilience, industry transformation, market access and development, and research and development • Market access and development, trade promotion and marketing, information and knowledge sharing • Industry coordination and governance, market access and development, research and training support, and capacity building • Market access and development, sustainability and climate resilience, research and development and smallholder and value chain transformation • Market access and development, sustainability and climate resilience, and research and development	• Sustainable fruit exports, water use, organic methods • IPM, soil health, cover crops, agroforestry, biodiversity, carbon sequestration • Climate strategy, resilience, tech adoption, irrigation, rootstock trials • CCC initiative, climate research, postharvest waste reduction, market intelligence • Efficient irrigation, CSA avocado farming, climate training, resilience research • CSA resilience, sustainability in litchi farming • Renewable energy, mulching, soil health, citrus sustainability, climate dialogue • Climate-resilient fruits, resource efficiency, global sustainability standards • Soil health, water use, CSA training, farmer education • Water strategy, carbon footprint, sustainability certification (SIZA, Global G.A.P.) • Irrigation optimization, producer certifications, GHG emission reduction	• Fruit SA Sustainability Initiative, SA GAP, WWF-SA partnerships • Linked to Fruit SA, participates in environmental best practices • Works with Hortgro under Fruit SA sustainability initiatives • CSA-aligned practices through Hortgro and Fruit SA • WWF-SA collaborations, GlobalG.A.P. certification, SAAGA best practices manual • Participates via Fruit SA Sustainability programmes • CGA-GDC training, Citrus Academy, GIZ-funded CSA programs, and CSA-focused mentorship, Citrus Academy CSA curriculum • Hortgro Science, WWF-Hortgro sustainable farming toolkit • Programs under SAAGA, SAMAC, and SALGA umbrellas • SAMAC Sustainability Framework, WWF collaborations, climate research partnerships • Participation in SANI-wide programs, Farmer development sessions
Research entities	• Citrus Research International (CRI)	• Soil science, sustainable crop production, fruit & nut farming	• Sustainable soil management, irrigation optimisation, climate resilience, fruit production, nut production	• collaborates with the Citrus Growers' Association (CGA) and academic institutions
Vegetables (in addition to the above)				

Industry bodies	• African Farmers' Association of South Africa (AFASA) • National African Farmers Union (NAFU) • SA Urban Food & Farming Trust • Potatoes South Africa (PSA) • Agri SA	• Advocacy and representation, and farmer development • Land reform and advocacy, smallholder farmer support, and capacity building • Policy advocacy, food security and nutrition, environmental sustainability, and community engagements • Policy advocacy, sustainability and environmental stewardship, Innovation and technological advancement, market expansion, and community development • Agricultural policy advocacy	• Sustainable agriculture, climate change education, risk mitigation, research collaboration • Policy advocacy, sustainable agriculture support • Urban agriculture, CSA techniques, soil health, hydroponics, vertical farming, policy reform • Potato research, drought- and disease-resistant varieties, sustainable practices, soil and water conservation, policy advocacy • CSA in livestock, sheep and goats, sustainable land use and farming	• Supported by NDA, AFASA, and FAO under "CSA for Smallholders" initiatives • Participates in national dialogues on CSA and transformation; engages with government and NGOs on sustainable farming models • Agrihub Initiative, Oranjezicht City Farm (OZCF), Environmental Entrepreneur Support Initiative (EESI), and AfriFOODlinks • Provides a platform Seed Potato Grower's Forum and Congress for industry leaders, farmers, agronomists, and scientists to collaborate and exchange ideas, driving forward innovations necessary for the sector's future • "Climate Resilience" and "Sustainable Agriculture" projects
Farmers bodies	• SA GAP Certification	• Food safety and quality, environmental sustainability, social acceptability, and economic viability	• CSA, good agricultural practices, soil conservation, efficient water use, agrochemical reduction	• Certification standards integrate CSA principles and are aligned with GlobalG.A.P. to ensure food safety and environmental sustainability
Research entities	• Agricultural Research Council (ARC) – VOPI • Universities (e.g. University of Stellenbosch, University of Pretoria, University of Free State, University of Limpopo, Fort Hare, KwaZulu-Natal, and North-West)	• Crop science, pest management, sustainable vegetable farming • Soil science, vegetable farming, climate adaptation	• Water-efficient irrigation, soil health, sustainable vegetable farming, South Africa • Soil health, sustainable irrigation, crop resilience, climate change, vegetable farming	• Roodeplaat Research Farm is a site for ARC-VOPI projects including climate-resilient crop breeding and CSA extension training, and Cedara Research Station works with Works with KZN Department of Agriculture on CSA innovation platforms, and Elsenburg Research Farm is linked with WCDoA CSA projects such as SmartAgri and climate-ready vegetable systems. • Various faculties

Other	Input suppliers	- Seed Companies: Syngenta, BASF, Sakata, Starke Ayres, Seminis, Syngenta, Enza Zaden, Hygrotech - Fertiliser & Crop Protection: DuPont, Omnia, Yara, Kynoch, Bayer Crop Science, Corteva - Irrigation Equipment Suppliers: Netafim, Agrico, Valley Irrigation, Microjet, Agri Technovation - Greenhouse and Hydroponic Suppliers: Greener Solutions, Urban Farming Co	- Crop protection products, pest management - Crop protection, seed genetics, and solutions - Crop protection, soil management, and nutrition - Agricultural technology, smart farming solutions	- Pest management solutions, integrated pest management (IPM), reduced chemical use - Reduced pesticide use, soil health, water use efficiency, vegetable farming - Reduced environmental impact, soil fertility, sustainable vegetable farming, South Africa - Sensors, drones, data analytics, water efficiency, pest management, farm productivity	- Syngenta's Good Growth Plan; Enza Zaden's resilient seed breeding; BASF's InVigor® hybrids; Starke Ayres' CSA-compliant vegetable trials - Yara's Climate Smart Agriculture Program; Omnia's Nutriology® and Green Revolution sustainable practices and nutrient efficiency trials; and Bayer's Carbon Initiative - Netafim's Sustainable Irrigation Projects; Agri Technovation's CropGPS and MYFARMWEB™ digital tools for efficient CSA input planning - Greener Solutions' energy-efficient greenhouse solutions; Urban Farming Co's urban CSA-aligned hydroponic modules
	Traders and processors	Processors – McCain, and Nature's Garden	Fruit export, market access, sustainability	Sourcing, water-efficient farming, organic farming, vegetable production, sustainability	McCain Regenerative Agriculture Framework; CSA pilot farms in SA (e.g., Lichtenburg); part of Sustainable Food Systems programs, CSA-related practices under contracted grower development and eco-efficient factory operations
	Exports and distributors	South African Fruit & Vegetable Exporters (SAFE)	Vegetable export, market access	Export, CSA techniques, climate resilience, sustainable vegetable exports	Linked to GlobalG.A.P. certification, WWF-SA partnerships, and participation in climate-resilient export initiatives

A wide range of institutions, companies, and value chain actors in South Africa are actively driving climate smart agriculture (CSA) across livestock, pork, horticulture and crop sectors. Key players include livestock associations and wool organisations promoting regenerative grazing, improved feed efficiency, and animal welfare; agribusinesses and cooperatives supporting sustainable feed, breeding and traceability systems; and research institutions investing in heat stress studies, sustainable soil management, pest-resistant crops, and CSA training programmes. Companies involved in veterinary health, feed, pest management and input supply are facilitating CSA by reducing chemical reliance and offering CSA-aligned solutions. Exporters and processors are also encouraging sustainable sourcing and energy-efficient practices. Various CSA projects highlight collaboration on low-cost, sustainable technologies and farmer capacity building.

Although there seems to be a wide interest, key gaps remain in: ensuring equitable access to technology; scaling CSA to smallholders; mainstreaming CSA finance, and ensuring consistent policy support and alignment across sectors among others. Opportunities exist in expanding CSA-specific financing mechanisms; training programmes; digital agriculture tools for precision farming and traceability; climate-resilient infrastructure; market-based incentives for CSA adoption; integrated water and soil health systems; CSA-linked certification; and effective and efficient CSA technologies.

While several South African institutions and value chain actors present some level of collaboration, opportunities for collaboration with the Dutch partners, particularly in areas aligned with Dutch strengths in sustainable agriculture, agri-tech and water management exist. For example, research entities working on CSA offer potential for joint research, innovation hubs and capacity building exchanges. Other opportunities include those in sector organisations engaged in regenerative grazing, feed efficiency, and traceability aligns well with Dutch expertise in precision livestock farming, animal health and low-emission technologies. Similarly, companies and cooperatives implementing efficient irrigation, water harvesting and sustainable soil management could benefit from Dutch innovations in smart irrigation systems, digital water risk mapping and agro-ecological zoning. The Netherlands can also contribute to expanding CSA-linked certification schemes, market access strategies and climate-smart financing models, areas where Dutch agribusiness and institutions have robust experience.

The stakeholders advancing CSA in South Africa demonstrate a growing convergence between environmental responsibility, technological innovation and market-driven sustainability. The climate smart activities that they are involved in need to be supported by efforts in capacity building, climate-resilient research, sustainable financing and technology adoption. Strengthening collaboration between public institutions, private actors and local farming communities will be critical to closing these gaps and realising the full potential of CSA in building a resilient and inclusive agricultural future.