Conservation Agriculture

A brief reflection of The Maize Trust supported research to date

Conservation Agriculture Farmer Innovation Program
19 September 2022

Principles of and motivation for CA

CA PRINCIPLES

1. Minimum mechanical soil disturbance (no-till seeding/ planting and weeding); < 15 cm or 25 % of soil surface.
2. Diversification of cropping system (rotation sand/ or sequences and/ or associations involving annuals and perennials, including legumes and cover crops with maximum living rootsin soil).
3. Maintenance of a permanent organic soil cover (crop residues and cover crops); minimum 30%, but aim for 100%.

COMPLIMENTARY GOOD PRACTICES

- Integration of animals
- Integrated soil fertility and acidity management

- Integrated weed management
- Integrated pest and disease management

Farming systems need to adapt and adress to these chalenges:

- Climate change
- Biodiversity loss
- Declining soil health
- Rising costs of production
- Declining productivity & profitability
- Rising debt
- Risk of defaulting farm failure or closure

The consequences of deep tillage practices include 46% of soil organic carbon is lost in SA's croplands resulting inseriously degraded soils & reduced production capacity.

DIFFERENT FARMING SYSTEMS IN SOUTH AFRICA

- *Conventional tilage* (CT) employs various primary and secondary tillage practices with grazing on the grazing lands (veld) only.
- *No-tilage* (NT) uses no-tillage planters with simple rotations, and livestock grazing the same as under CT (taking place on the veld only).
- *Conservation agriculture* (CA) uses no-tillage practices, but also employs a more complex crop rotation system, integrating cash crops with cover crops for the livestock. Livestock is used intensively in both the grazing area and croplands.

CA offers an important and practical solution that can:

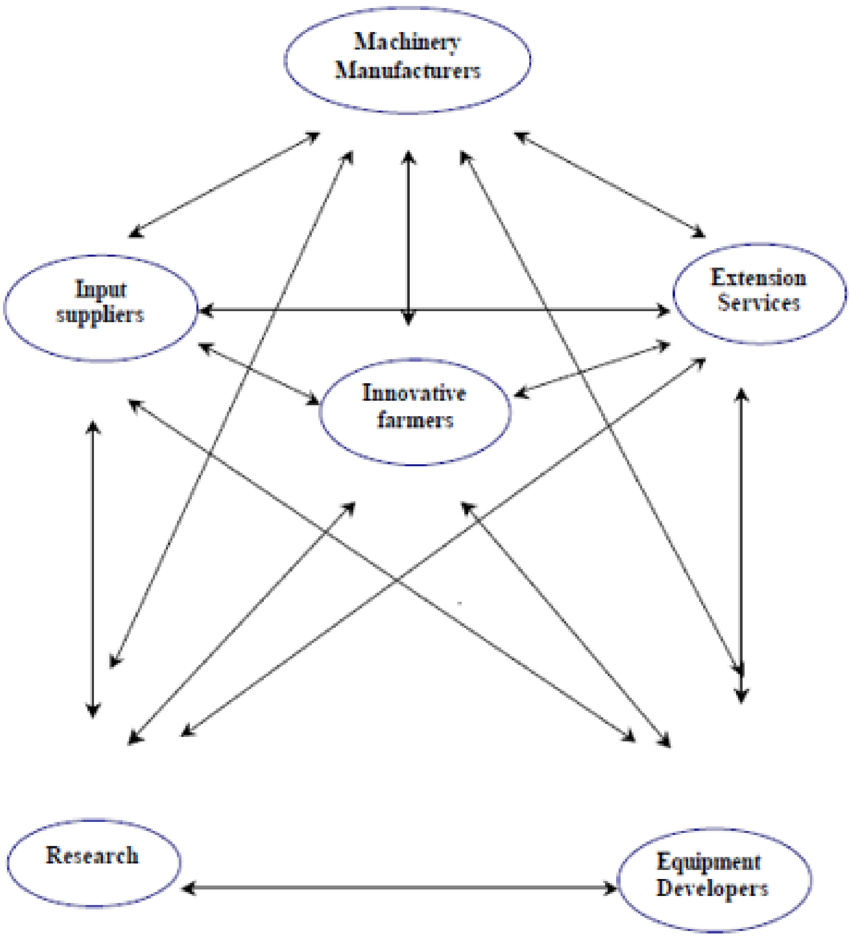
- Adapt & mitigate climate change
- Hedge against financial stress
- Provide long-term financial viability
- Restore soil health

These solutions offer benefits:

- Reduce risk & build more resilience
- Positive impact on soil & water health
- Higher C-sequestration rates (+Credits)
- Higher, stable production and profitability
- Improved input use efficiency (reduced input costs)
- Reduced capital, maintenance & replacement costs

Healty soils are the cornerstone of agriculture, providing FREE functions and services.

Research approach and implementation



> *« Farmer-centered Innovation Platforms scientifically proven to work the best for CA research (on the left).*

HOW DID WE JOIN AND SUPPORT AN EXISTING FARMER-LED INNOVATION MOVEMENT?

Scientific principles:

- On-farm, farmer-centered
- Co-learning (by doing)
- Continuous interaction and dialogue
- Facilitation on all levels

SCIENTIFIC THEORY & APPROACH

- GOAL > To facilitate research, development and adaptation of appropriate CA systems for a range of unique contexts in South African grain farming regions.
- MAIN ACTIVITIES > On-farm research; Creation of wider awareness and innovation capacity.
- KEY INITIATIVE > CA Farmer Innovation Programme (CA FIP); Grain SA - ASSET Research, The Maize Trust.

CA FIP PROJECT TEAMS & ON-FARM RESEARCH TRAILS

1

Ottosdal

No-till Club, Dr Andre Nel, Gerrie Trytsman, NWU, Dr Hendrik Smith

> 80 ongoing trails

2

Mpumalanga

CA farmer networks, Drs Jaap Knot & Hendrik Smith, Gerrie Trytsman, NWU

> 3 ongoing trails

3

Maluti

CA farmer networks, Drs Jaap Knot & Hendrik Smith, Gerrie Trytsman, NWU

> 2 ongoing trails

4 Reitz & Vrede

Riemland and
Ascent study groups, VKB, Gerrie Trytsman, NWU, Dr Hendrik Smith, ARC

> 24 completed trails

5

Smallholder in KZN

Numerous
farmer learning groups & Mahlathini Development Foundation, NWU

> 40 ongoing trails

The trails...

KEY TRAIL TOPICS

- CA vs CT (yields, finance)
- Crop density (plant population and row width)
- Crop rotations (cash crops)
- Cover crops (CC) and Livestock integration
- CA implements

KEY INDICATORS MEASURED

- Production - yields, biomass, water use efficiency (WUE)
- Economics and finances
- Soil health (Haney SHT and many other)
- Biodiversity, e.g., dung beetles
- Carbon footprint
- Visual field tests: Erosion/ ground cover, Water infiltration, slaking, structure, soil profiles & roots, earthworms, weeds, insects, etc.

LESSONS LEARNED AND IMPLICATIONS FOR NEW ON-FARM TRAIL DESIGN

New treatments from 2020 onwards:

1. CT: Conventional tillage systems
2. NT: No-till with high inputs and simple rotations e.g., maize x soya
3. CA with integrated crop-livestock system (ideal, best CA system) - *see below*
4. Veld (control)

CA/ RA integrated crop-livestock system (eastern summer rainfall areas, South Africa)

- (LEFT) Season 1: Grain cash crop + relay/ inter cropping + Livestock (e.g., maize & WCCs)
- (MIDDLE) Season 2: Annual Mixed Double Cover crops (summer + winter) + Livestock
- (RIGHT) Season 3: Grain cash crop + WCC + Livestock (e.g., soya & WCCs)

CA/ RA integrated crop-livestock system (western summer rainfall areas, South Africa)

- (LEFT) Season 1: Cash crop (e.g., maize)
- (MIDDLE) Season 2: Summer Cover Crop + Livestock
- (RIGHT) Season 3: Grain cash crop + WCC (intercrop) + Livestock (e.g., Sunflower & WCCs

Research results: Yield

Maize grain yield and rainfall use efficiency of conventionally tilled mono-culture and three CA crop systems on a sandy loam soil during six consecutive seasons near Ventersdorp in the North West Province
(Maize Trust funded project from 2008/2009 to 2015/2016)

FACTORS AFFECTING MAIZE YIELD:

- No-till with a soil cover of crop residues: maize in monoculture increased by 40% over that of the conventionally tilled system.
- Rotating the maize with a legume in no-till with soil cover, the yield increase was 45%.
- Rotating it with millet and a legume in a three-year system, the yield increased was 59%.
- These increases are due to the improved infiltration of rainwater and less runoff as well as the “rotational effect” where the yield of maize often improves by rotating it with other crops.
- Similar improvements were found for the rainfall use efficiency. This is important as rainfall is the most limiting natural resource.

Season	Crop system				Significance level
	Conventionally tilled mono-culture maize	No-till mono-culture maize	No-till legume - maize	No-till millet - legume - maize	
	Yield (t ha^{-1})				
2010/11	5.79	5.80	6.38	7.28	<0.01
2011/12	2.40	3.07	2.21	3.04	0.22
2012/13	1.64	3.81	4.28	4.38	0.03
2013/14	8.69	8.54	9.03	9.788	0.18
2014/15	2.82	6.28	6.93	7.628	<0.01
2015/16	1.09	3.87	3.70	3.60	<0.01
Mean	**3.74**	**5.23**	**5.42**	**5.95**	
	Rainfall use efficiency (kg ha^{-1} mm^{-1})				
2010/11	9.65	9.67	10.63	12.13	<0.01
2011/12	5.98	7.65	5.51	7.57	0.20
2012/13	3.03	7.05	7.91	8.09	0.02
2013/14	14.26	14.02	14.83	16.06	0.18
2014/15	4.07	9.06	10.00	11.00	<0.01
2015/16	2.38	8.46	8.10	7.87	<0.01
Mean	**6.56**	**9.32**	**9.50**	**10.45**	

(Nel, A. (2017). Evaluation of conservation agriculture principles on two soil types on the Highveld. Final progress report to The Maize Trust.)

Farm 1: Ottosdal, NWP

Maize yield: conventional tillage versus no-till

Conventional tillage:

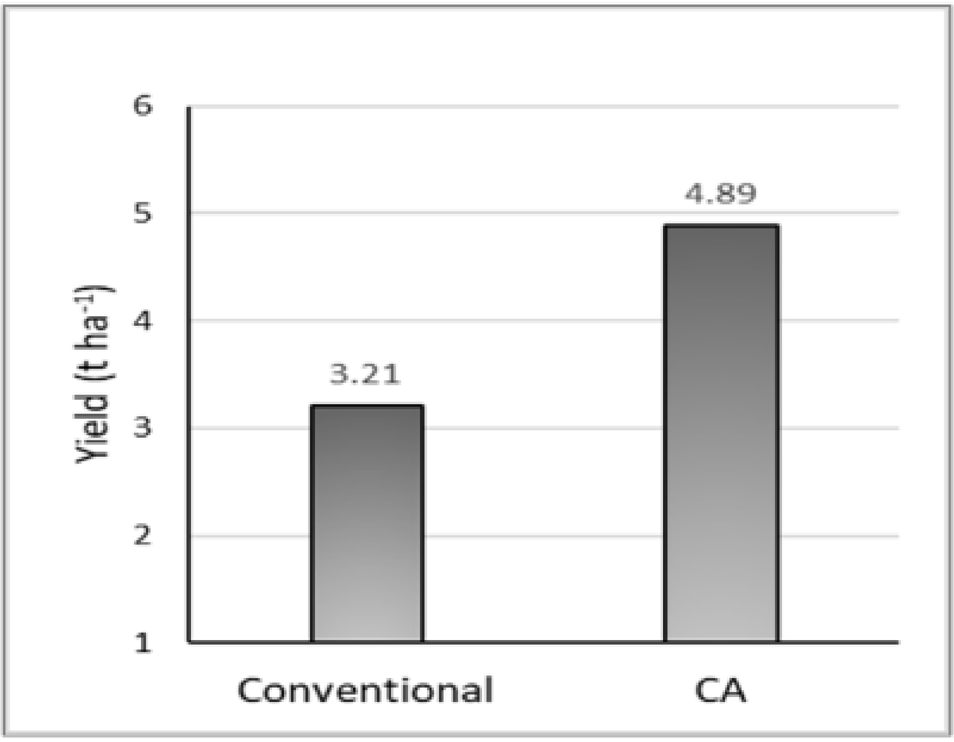
- Rip-on-row
- 2 x 2.3 m + 1 x 1.5 m row spacing
- 20 000 plants per ha

No-till:

- Maize + residue cover
- 0.52 m row spacing
- 40 000 plants per ha

Results:

- The three-year mean no-till maize yield was 1.68 t ha-1 (52%) higher than the conventional yield, mainly due to a three- to fourfold increase of the water infiltration rate.



(Smith et al., 2018)

Farm 2:

The yield of maize (t ha-1) as affected by cropping system in the Ottosdal area.

Cropping systems:

- CA1: No-till, 2 m spaced rows, 40 000 plants ha-1,
- CA2: No-till, 0.91 m spaced rows, 27 000 plants ha-1,
- CT1:Moldboard ploughing 0.25 m deep, 0.91 m spaced rows, 24 000 plants ha-1, and
- CT2: Rip-on-row 0.45 m deep, 1.5 m spaced rows, 33 000 plants ha-1

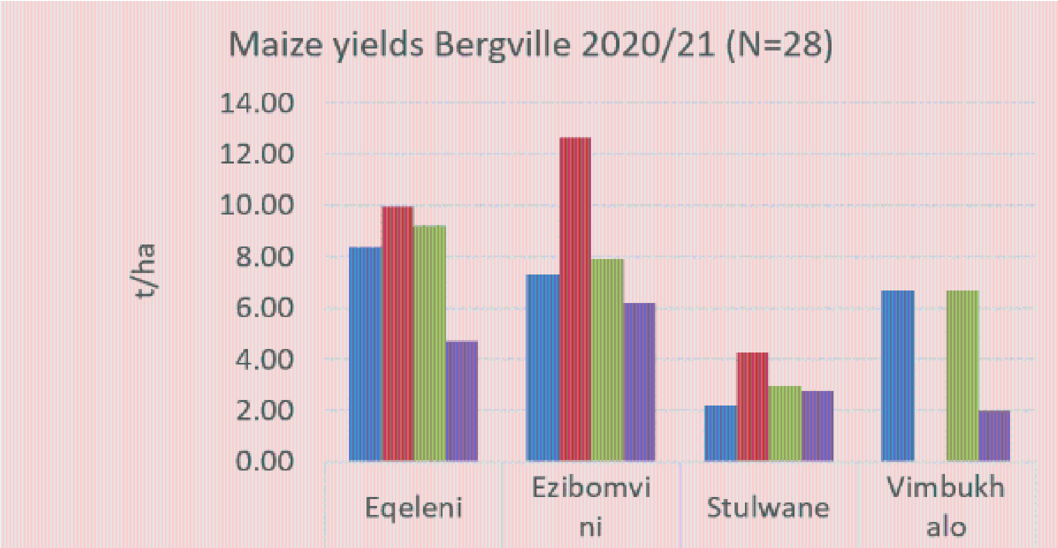
[redacted]

Farm 3:

The yield of maize (t ha-1) as affected by cropping system in the Ottosdal area.

Cropping systems:

- CA1: No-till, 2 m spaced rows, 40 000 plants ha-1,
- CA2: No-till, 0.91 m spaced rows, 21 000 plants ha-1
- CT: Strip tilling 0.3 m wide and 0.25 m deep, 1.5 m spaced rows, 2 000 plants ha-1



	Eqeleni	Ezibomvini	Stulwane	Vimbukhalo
Average of yield(t/ha)CA-M	8.35	7.29	2.21	6.67
Average of yield(t/ha)CA-M intercrop	9.95	12.62	4.25	
Average of yield(t/ha)CA	9.21	7.90	2.96	6.67
Average of yield(t/ha)Control	4.71	6.21	2.75	1.98

Productivity for smallholders: Yields (Bergville):

- Average yields for maize planted in intercropped plots (M+B , M+CP, M+Pk) are much higher than the yields in maize only plots.
- Average yields for the CA trial plots (intercropped and maize only averaged) are much higher than maize yields in the CA control plots (planted to maize only in consecutive years).

> *Yield advantages for maize through intercropping and crop rotation are evident after a continuous CA implementation cycle of 4 or more years »*

Plant density effect on yields (Ottosdal trial results, 2014-2018)

««(left) Density: <24 000 x 0.76-0.9 m:

(lower yields)

- Less crop residues
- Less roots
- More weeds
- Lower WUE

»»(right) Density: 40 00 x 0.52 m:

(higher tields)

- Quicker build-up of soil cover
- More roots
- Less weeds
- Better WUE

Research results: Integrated crop-livestock systems and bio-physical aspects

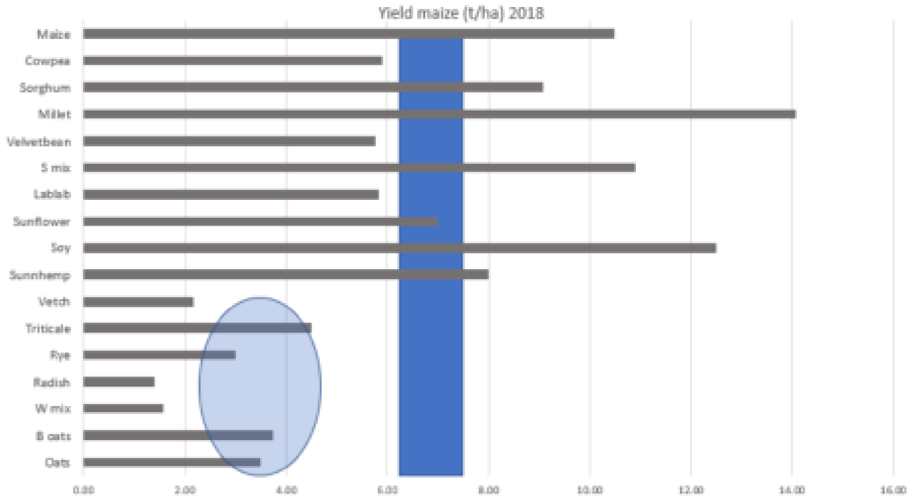
Assessment of cover crops & livestock integration (9 years, CA FIP projects). The aims were to increase knowledge and management of CA tools, such as:

- *Biodiversity*: biomass production and adaptability of cover crop functional groups + multi-specie mixtures
- *Intensification*: green fallow, intercrop and rotation systems
- *Integration*: Livestock (sheep and cattle)
- *Grazing systems*: Intensity and frequency of grazing (HUG)

Key findings on cover crop & livestock integration trials:

- Improvementin soil health (water and nutrient cycles)
- Increase in the amount and quality of soil cover
- Significant improvement in cash crop yield during drought seasons
- Reduction in agro-chemical use, especially fertilizer without yield penalties
- Increased biodiversity (above- and below-ground)
- Weight gain from 30% biomass (cattle) - 220-240 kg/ha/summer season
- Reduced risk by diverse income generation
- Improved financial viability (medium- to long-term)
- There is not a right or wrong decision (better or worse)•Respond to the situation and use the tools - adaptive management is key

TESTING THE EFFECT OF COVER CROPS ON MAIZE YIELD, OTTOSDAL



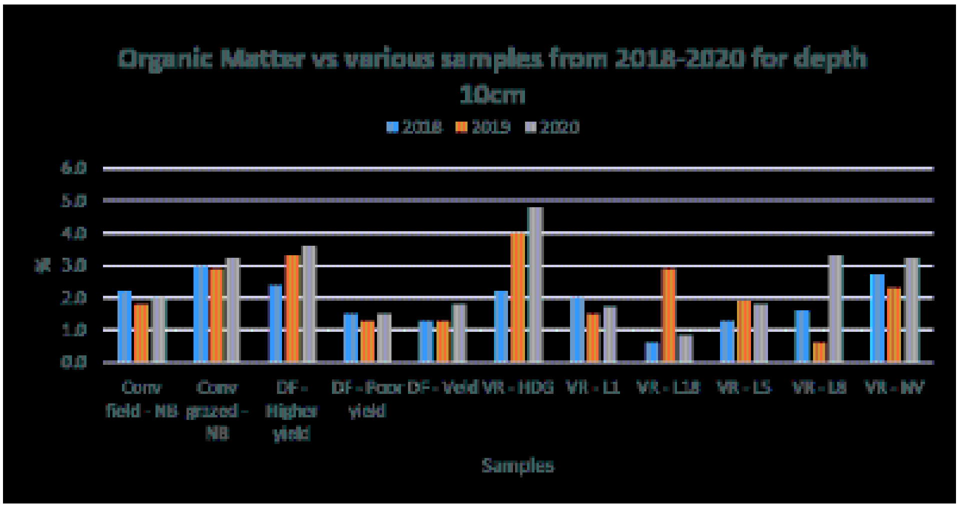
(Smith et al., 2018)

Year	Rain mm	Yield t/ha	Kg grain/mm of rain
2013/14	609	7,4	12,5 kg
2014/15	372	2,7	7,2 kg
2015/16	412	2,7	6,5 kg
2016/17	608	8,9	14,6 kg
2017/18	398	7,3	18,3 kg

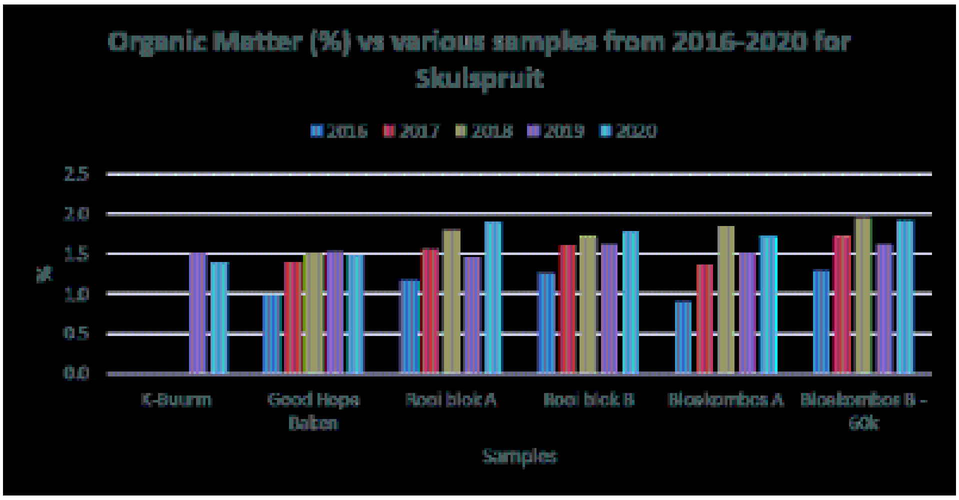
WATER USE EFFECIENCY OF MAIZE, OTTOSDAL, (Smith et al., 2018)

- Effective rainfall values from October to May; Not considering soil water content before planting and after harvesting the grain. Average WUE for maize in SA is 8 kg/mm/yr.

MONITORING SOIL HEALTH ON FIXED FARMER-LED TRAIL SITES (comparing
different systems or ‘treatments')



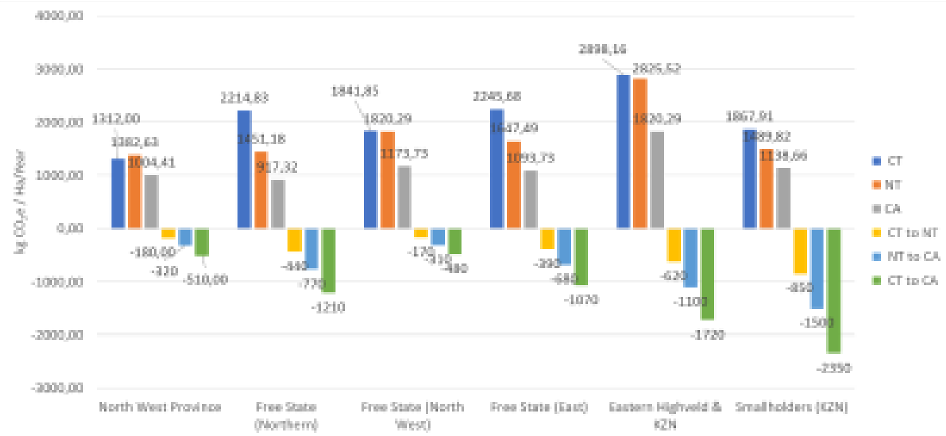
REITZ



VREDE

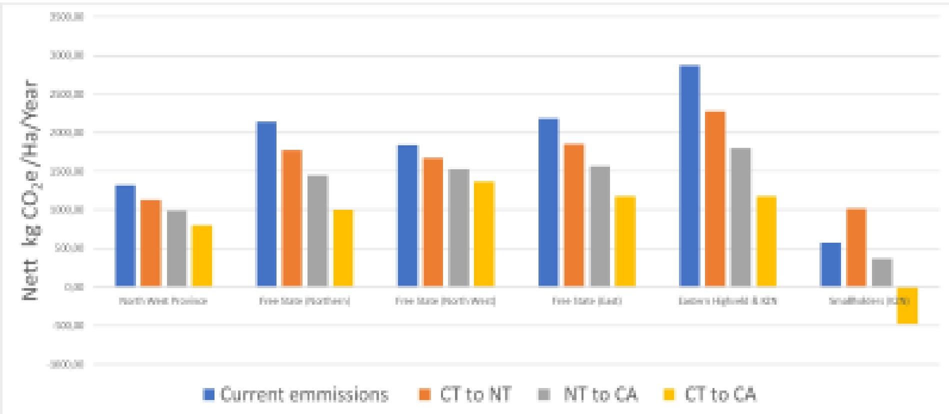
CARBON FOORPRINT RESULTS:

Current CO_2 emissions for each system vs. the sequestration potential of transitioning from conventional tillage to No-till and CA farming systems for Maize per region. »»



(Smith et al., 2021)

The Nett kg CO_2e calculated from current emissions and the sequestration potential for each region in the transition to No-till and CA systems espectively for Maize. »»



(Smith et al., 2021)

Carbon sequestration website

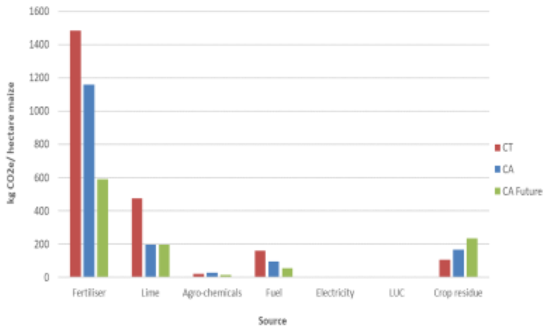
Carbon footprint videos:

- Part 1: Introduction. The carbon footprint of Summer Maize Farming Systems in South Africa.
- Part 2: Carbon Emissions & Carbon Sequestration. The carbon footprint of Summer Maize Farming Systems in South Africa.
- Part 3: Results from the work completed with The Maize Trust. The carbon footprint of Summer Maize Farming

Systems in South Africa.

GREENHOUSE GAS EMISSION CONTRIBUTION FROM PRODUCTION INPUTS

- HOT SPOT: N fertilisers used in CT systems contributes to 60-70% of the emissions.

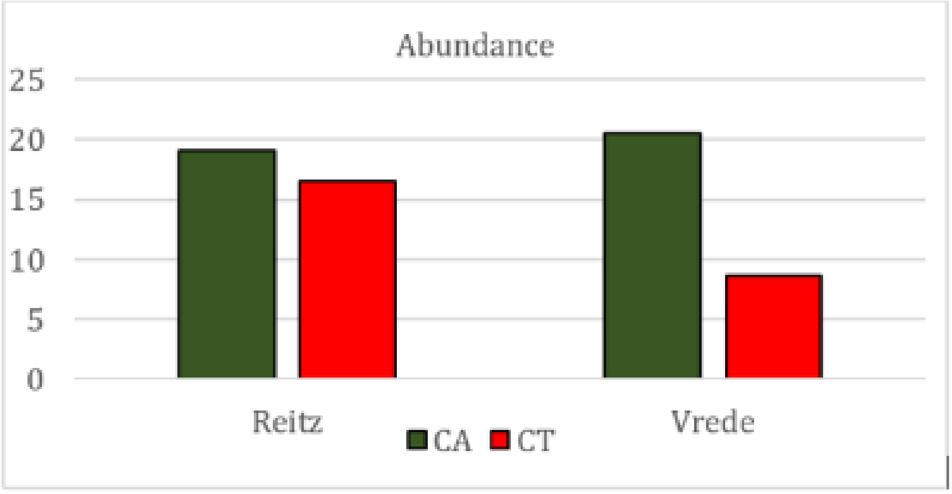


(Smith et al., 2021)

CA AND BIODIVERSITY

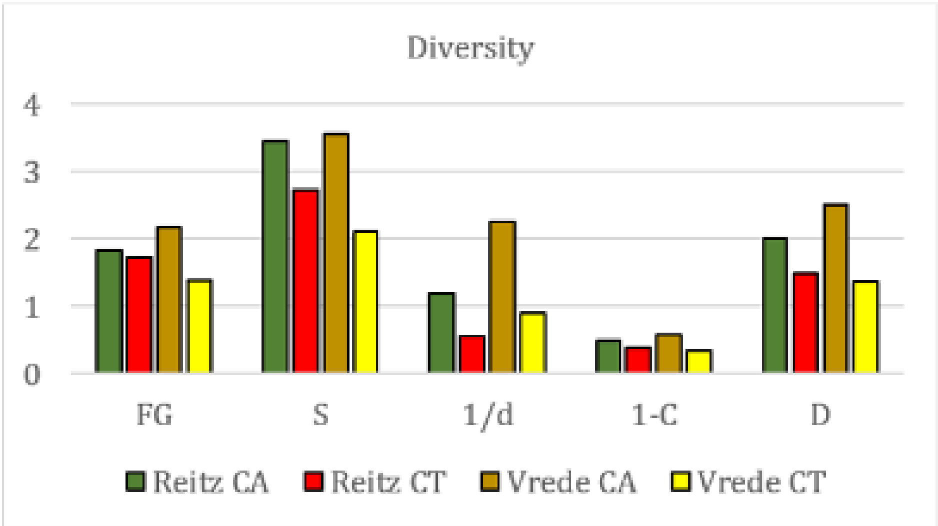
DUNG BEETLES

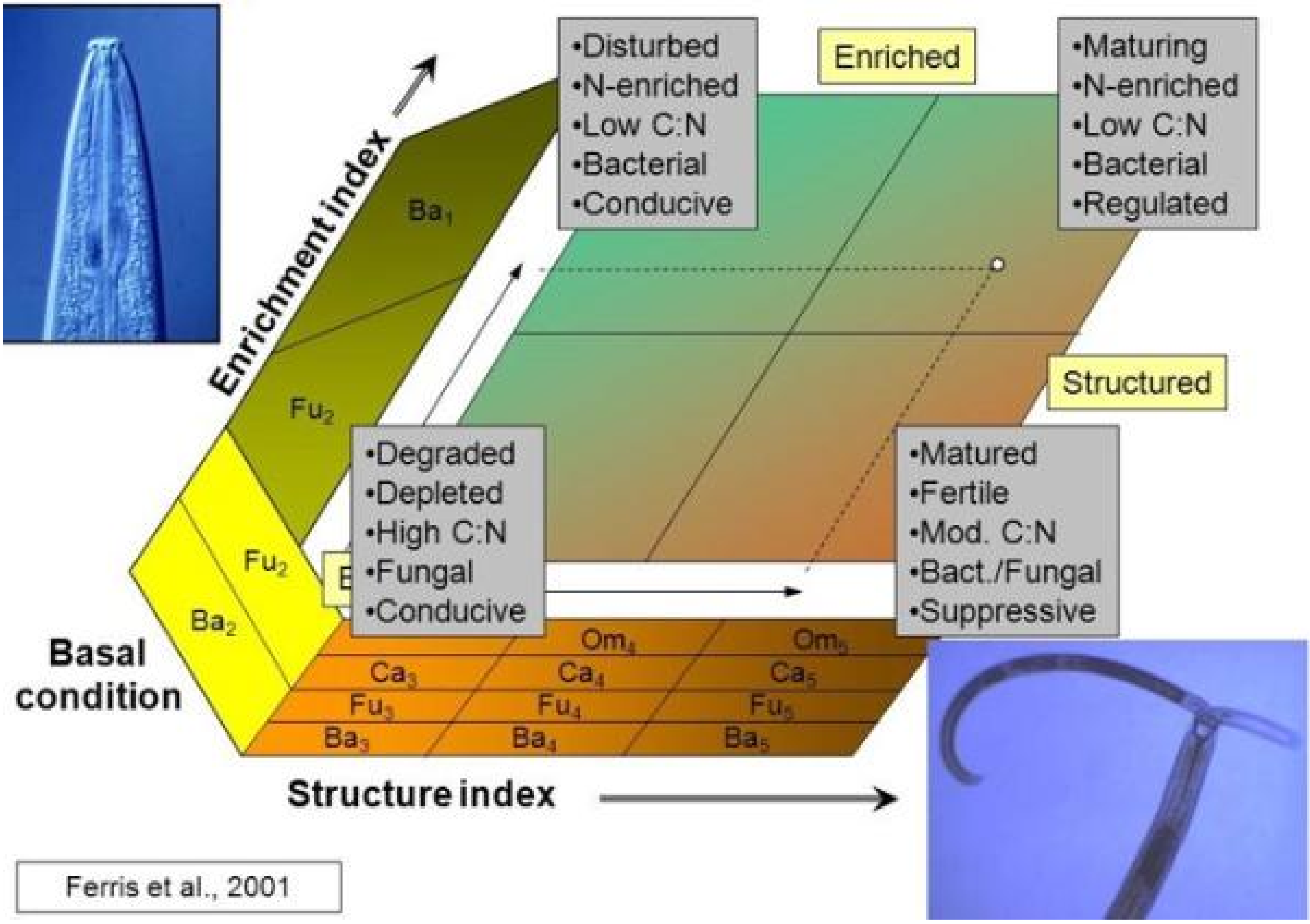
Differences in dung beetle ***abundance*** in different agricultural practices in the Reitz and Vrede areas.



(Smith et al., 2020)

Differences in dung beetle ***diversity*** in different agricultural practices in the Reitz and Vrede areas.

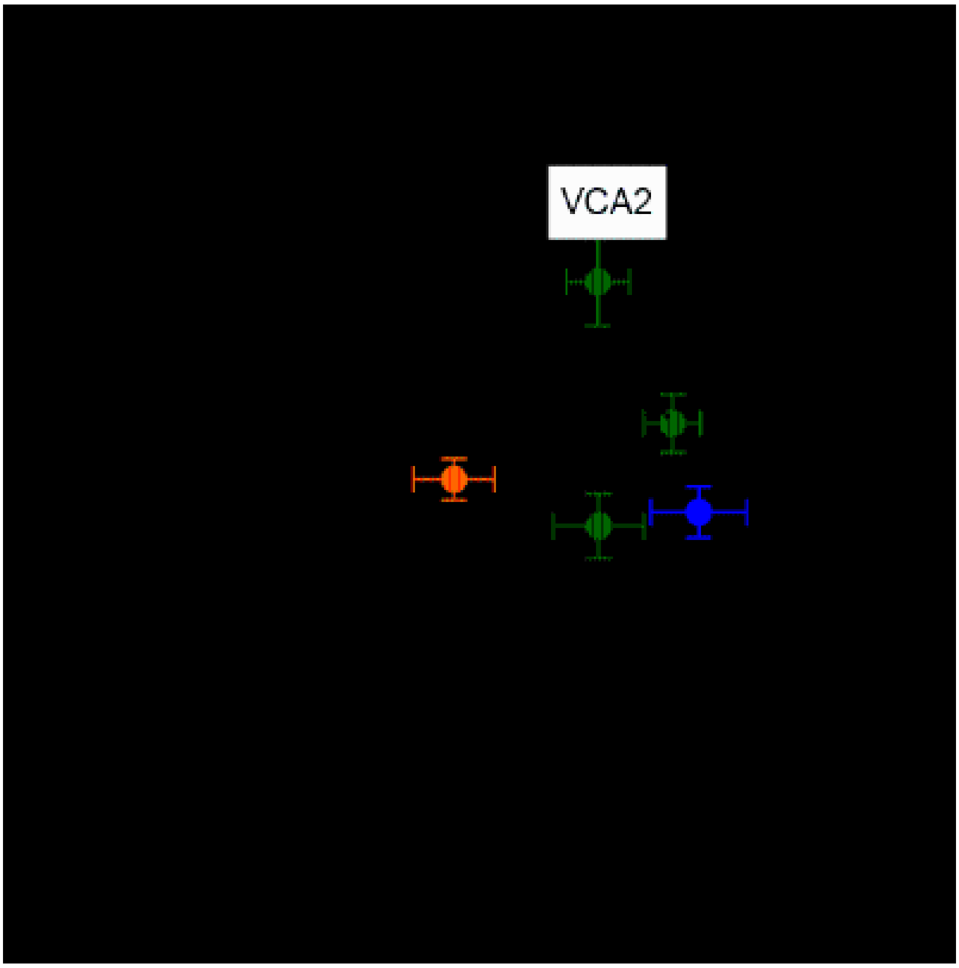




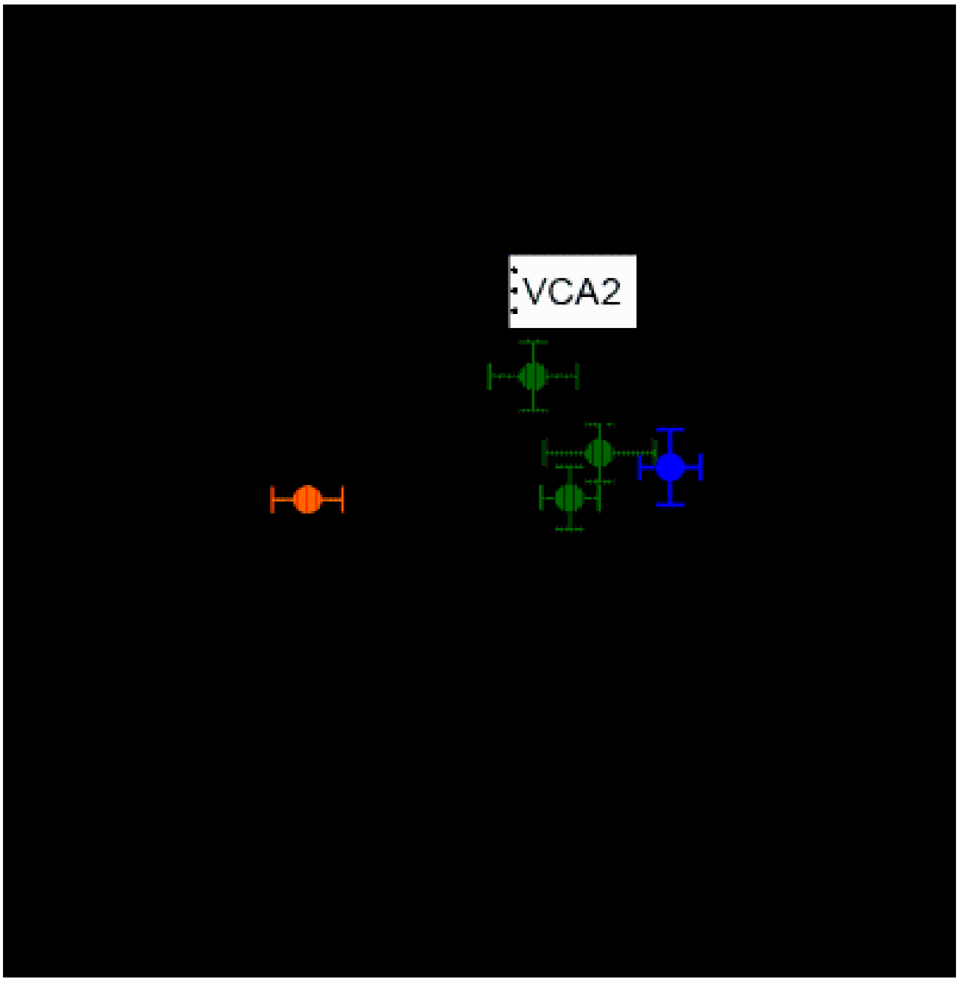
NEMATODE-BASED SOIL HEALTH INDICES:

- Measure soil ecosystem (soil food web) health and functioning
- Measure recovery or restoration of soils health
- A good indicator of recent changes in soil heath status

Results: Soil food web status in farmlands under CA, Vrede study area (Loggenberg, 2021).



1st Sampling interval



2nd Sampling interval

Research results: Financial impacts

(Free cash flows (profit), Production costs.)

(Sources: Conv & NT: Grain SA 2021/22 online production reports. CA/RA: Maize Trust CA field trials 2021/22)

Declining soil health (fertility)..

..leads to increasing input volume requirements and cost.

This is amplified by rising costs of fertiliser, agro-chemicals, and overheads.

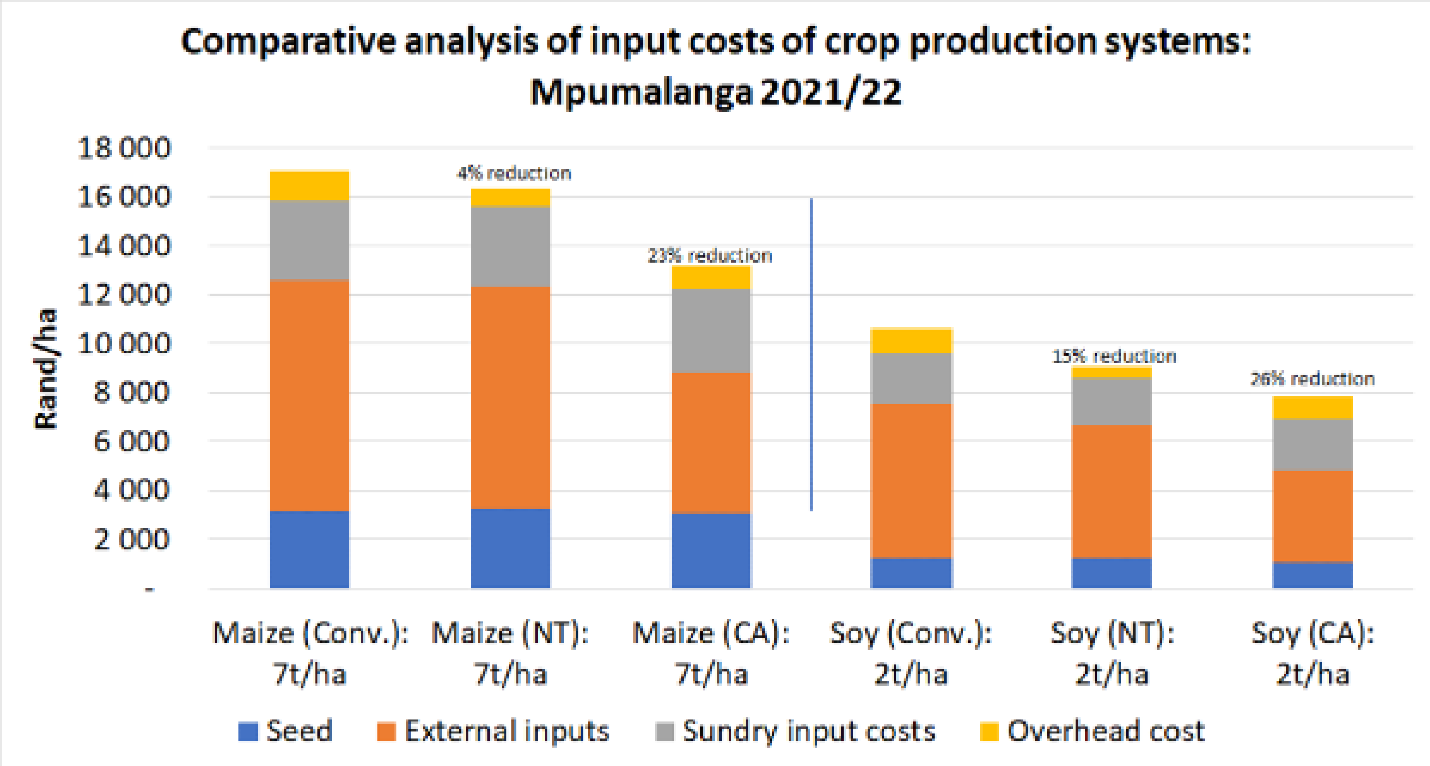
The combination is unsustainable.

Conservation Agriculture provides the solutions to overcome these problems

But support is needed through the transition phase for CT to CA to
strengthen/ fasten the performance and impact of CA.

CA/RA requires..

..a paradigm shift, awareness, ecological literacy and an investment in acquiring new knowledge, skills and tools (livestock and equipment).



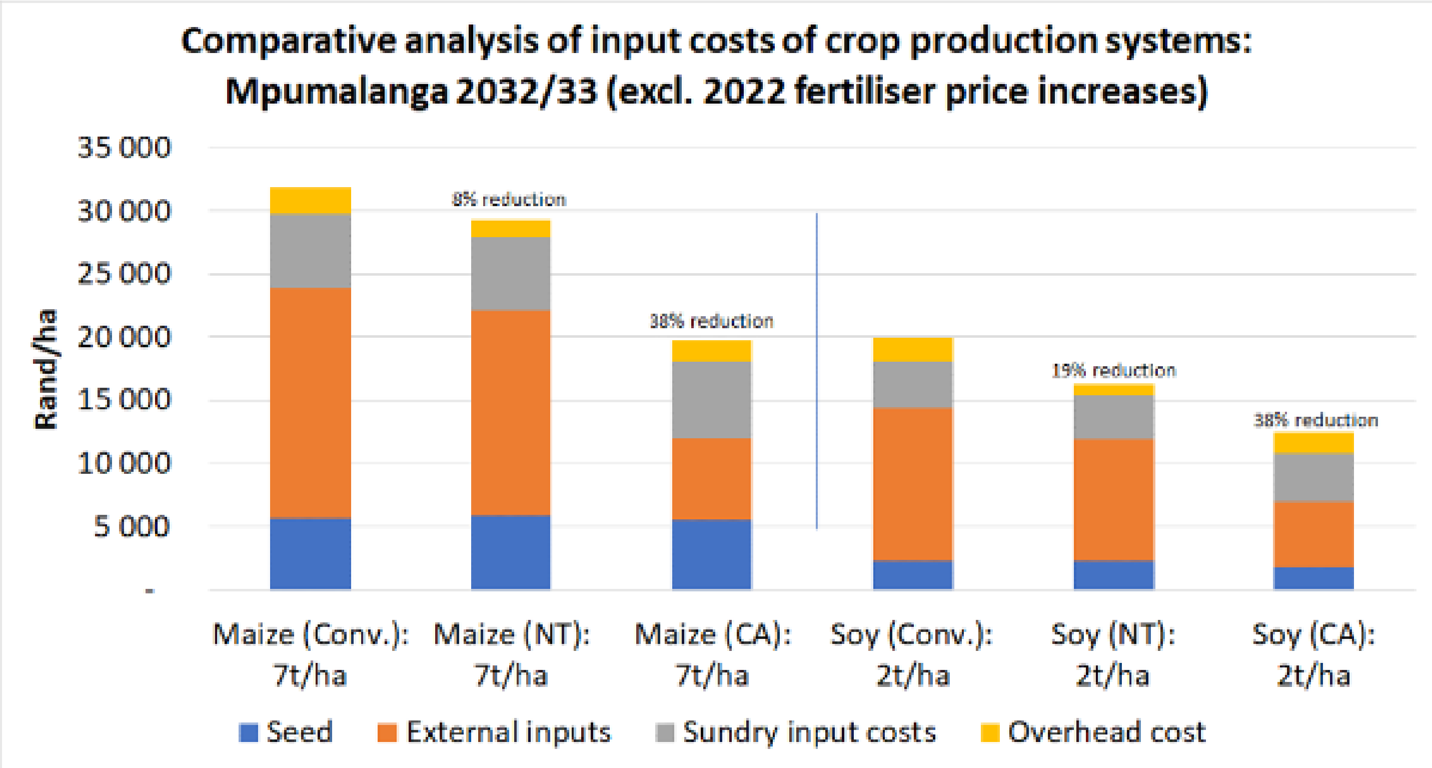
MPUMALANGA

Cost comparisons of various farming systems as per typical production accounts of the Mpumalanga area for the 2021/22 season.

- External inputs = fertilizer, lime, fuel, reparation, herbicide, pesticide
- Sundry inputs = insurance, hedging, interest
- Overhead costs = capital, equipment, replacement, maintenance

Sources:

1. Conv & NT: GrainSA 2021/22 online production accounts
2. RA: ASSET Research in-field trials 2021/22

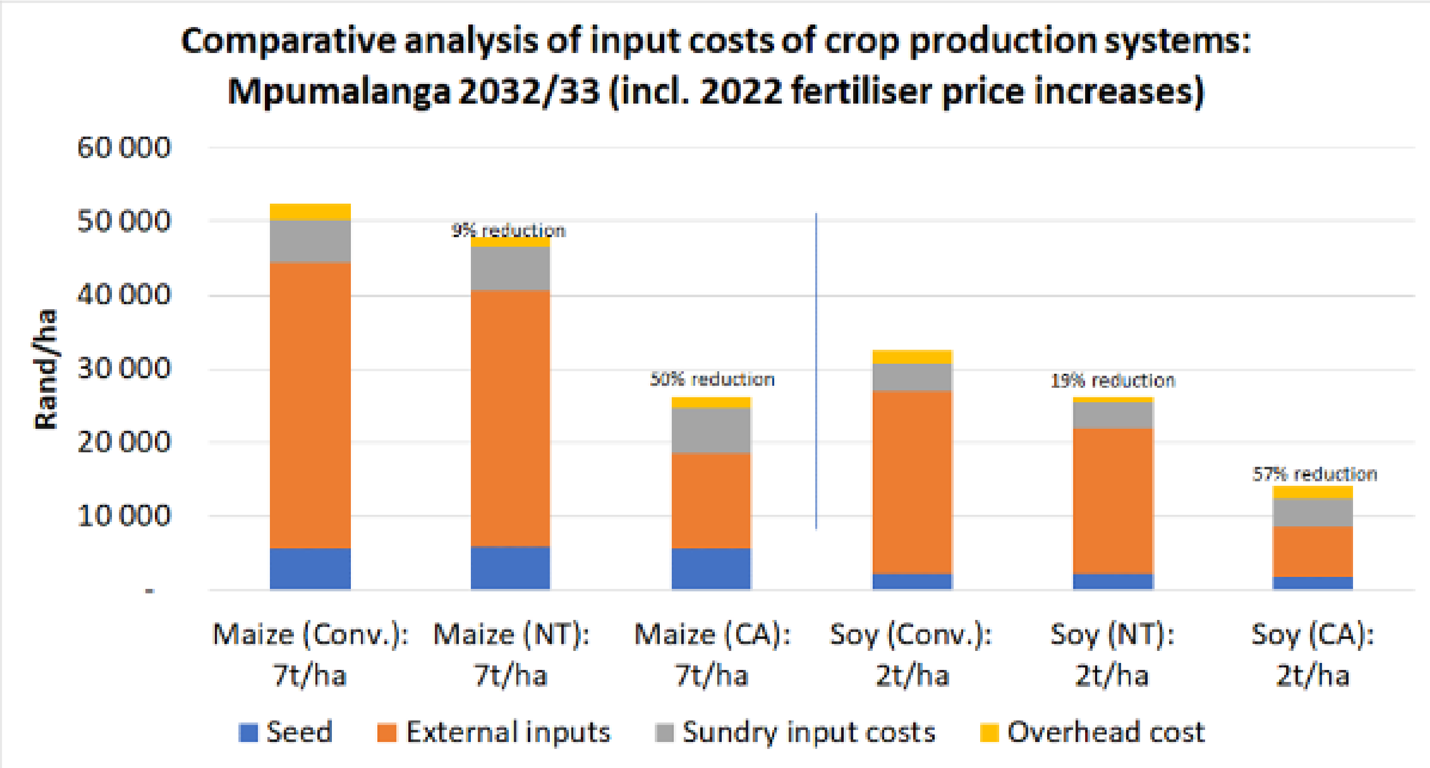


Cost comparisons of various farming systems for the Mpumalanga area for the 2032/33 season assuming NO price increase of fertilizers in 2022.

- External inputs = fertilizer, lime, fuel, reparation, herbicide, pesticide
- Sundry inputs = insurance, hedging, interest
- Overhead costs = capital, equipment, replacement, maintenance

Source:

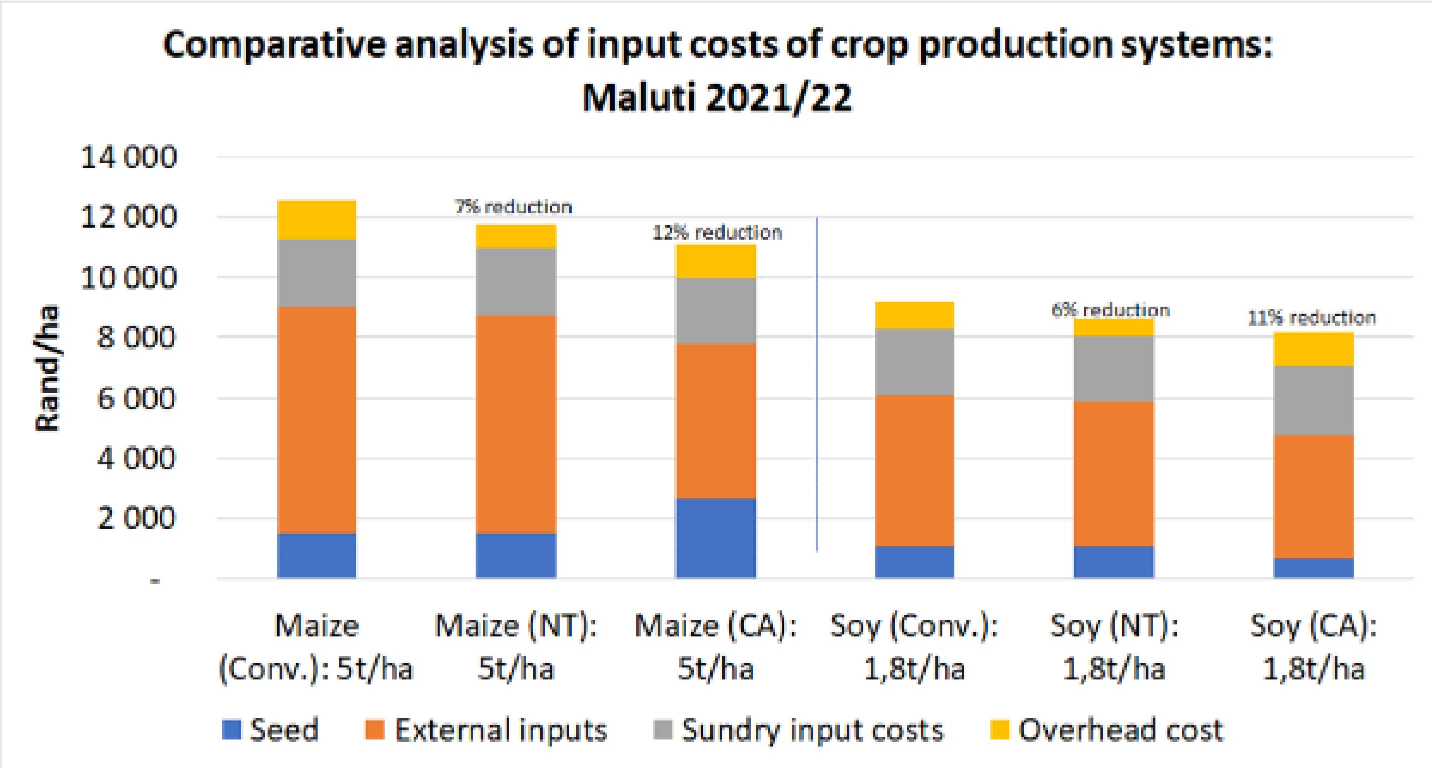
1. Model values: https://sagrainmag.co.za/2022/05/03/financial-benefits-of-converting-to-ca/



***Cost comparisons of various farming systems for the Mpumalanga area for the 2032/3 season assuming a once-off 200% price increase of fertilizers in 2022*.**

Source:

1. Model values as per the previous, but added a once-off shock to fertilizer prices of 200%



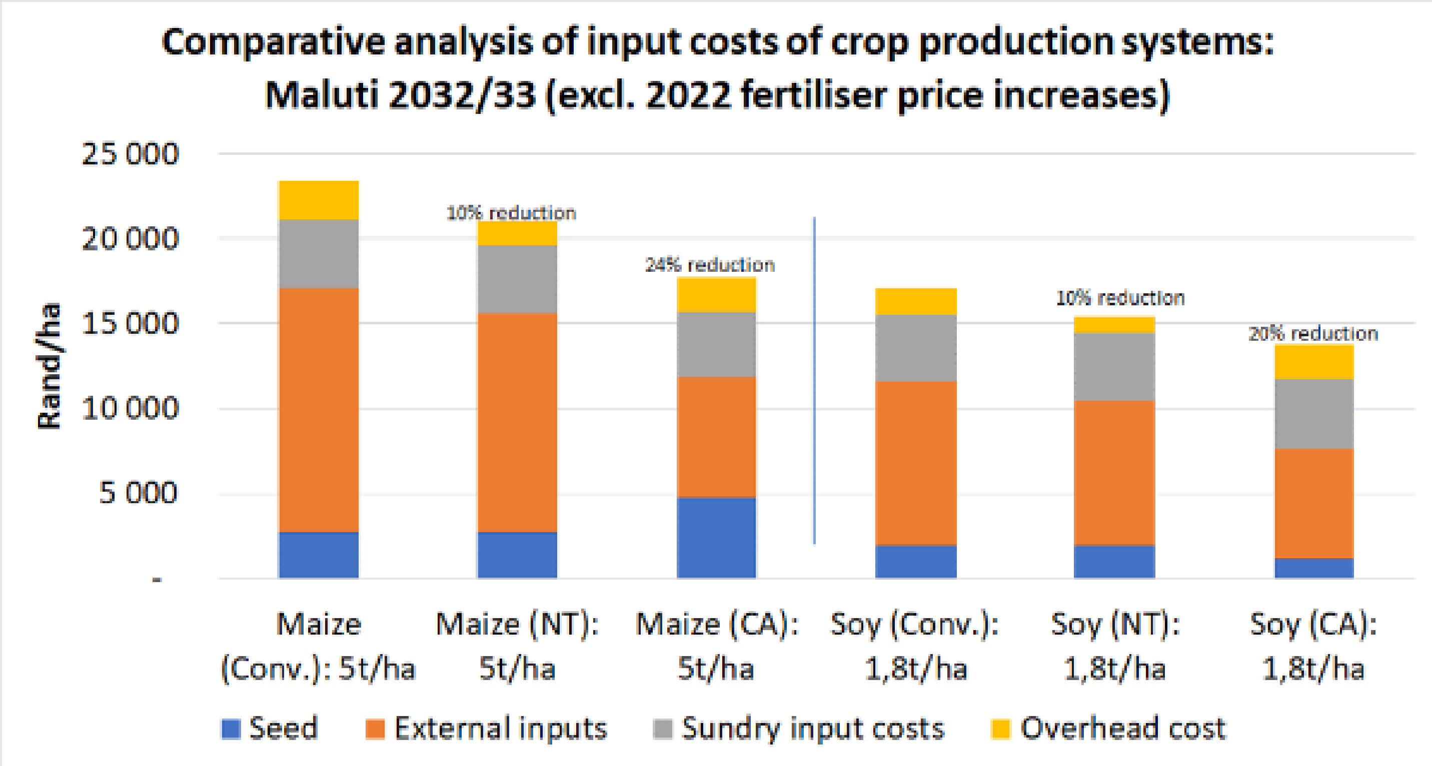
MALUTI

Cost comparisons of various farming systems as per typical production accounts of the Maluti area for the 2021/2 season.

- External inputs = fertilizer, lime, fuel, reparation, herbicide, pesticide
- Sundry inputs = insurance, hedging, interest
- Overhead costs = capital, equipment, replacement, maintenance

Sources:

1. Conv & NT: GrainSA 2021/22 online production accounts
2. RA: ASSET Research in-field trials 2021/22



Cost comparisons of various farming systems for the Maluti area for the 2032/33 season assuming NO price increase of fertilizers in 2022.

- External inputs = fertilizer, lime, fuel, reparation, herbicide, pesticide
- Sundry inputs = insurance, hedging, interest
- Overhead costs = capital, equipment, replacement, maintenance

Source:

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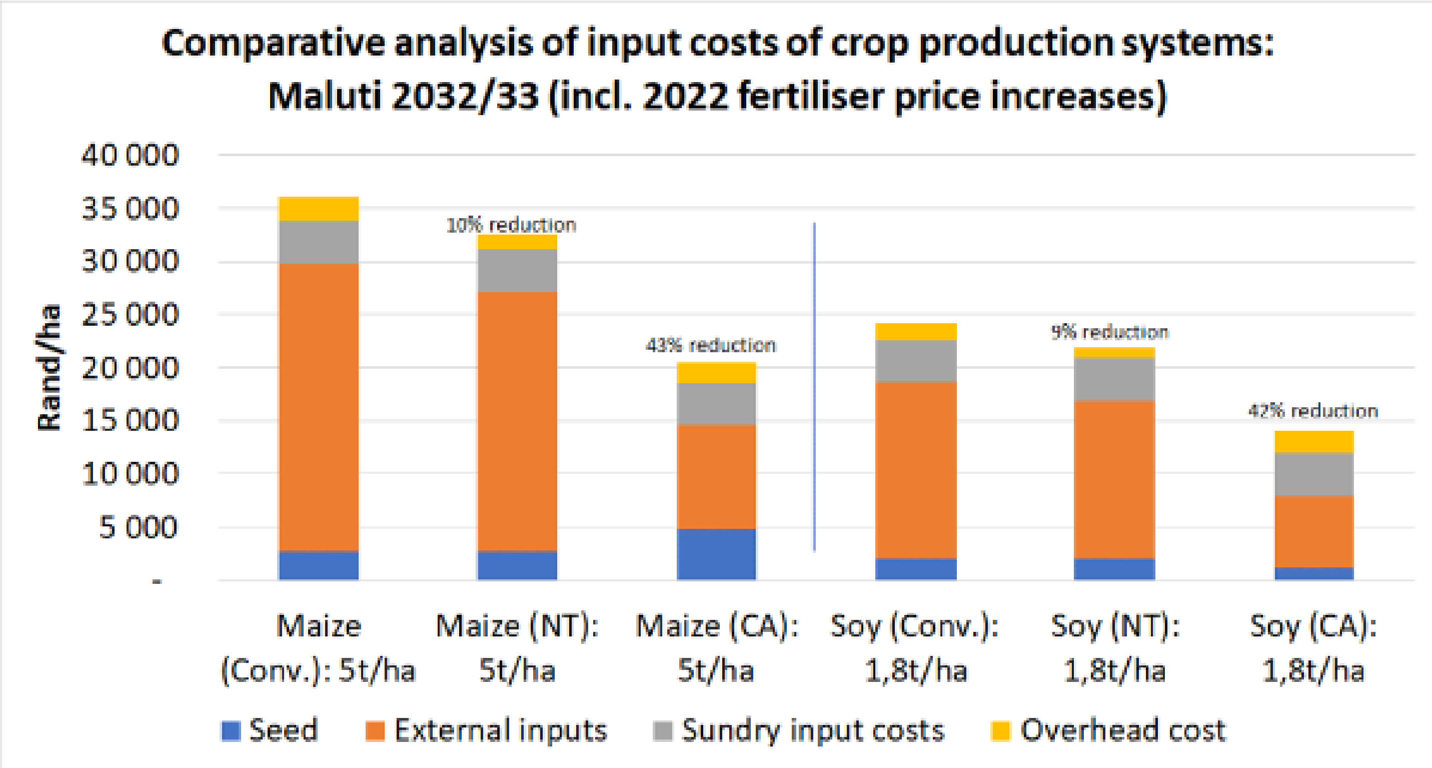

Cost comparisons of various farming systems for the Maluti area for the 2032/33 season assuming a once-off 200% price increase of fertilizers in 2022.

Source:

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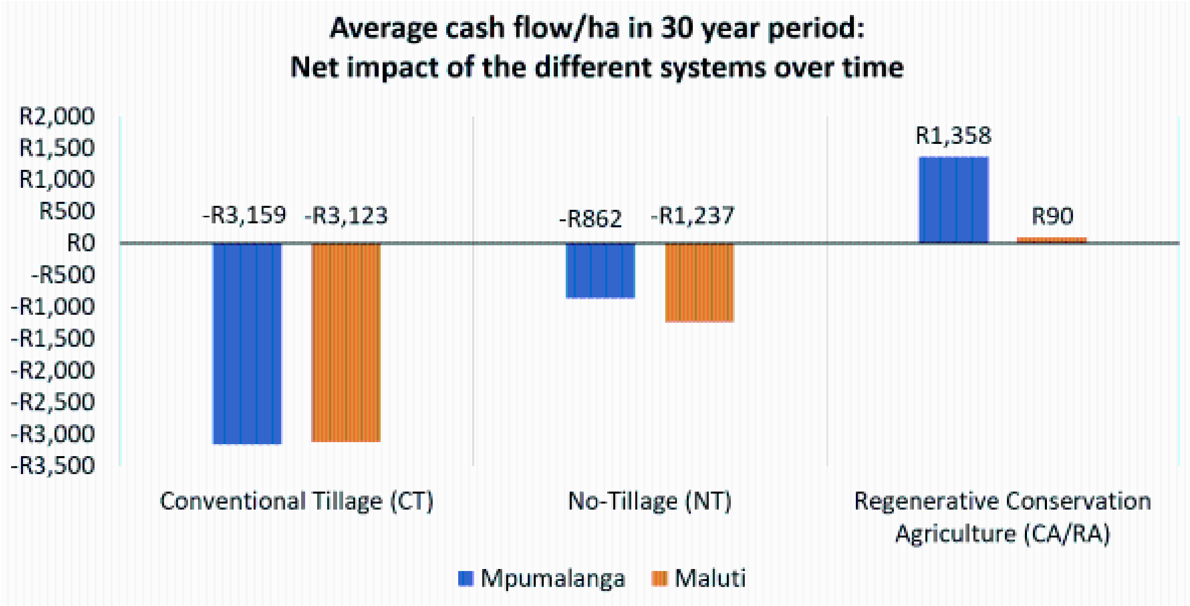
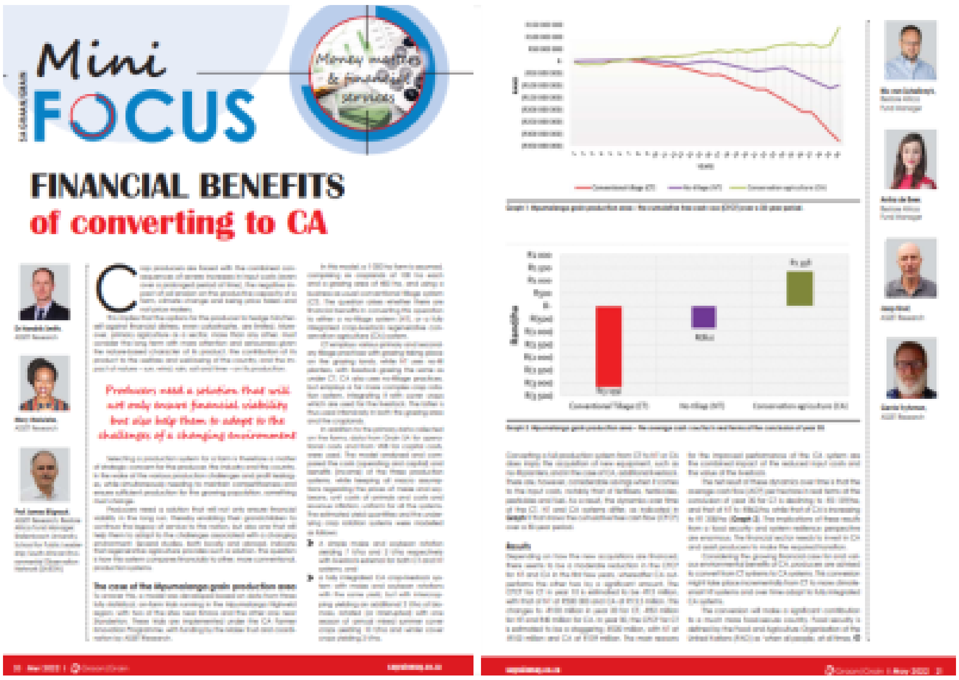


Grain SA. Money matters and financial services, Mini focus. 5 May 2020. Financial benefits of converting to CA/RA. Available online: https://sagrainmag.co.za/2022/05/03/financial-benefits-of-converting-to-ca/


Mini FOCUS

Money matters & financial services

FINANCIAL BENEFITS of converting to CA

Grain SA. Money matters and financial services, Mini focus. 5 May 2020. Financial benefits of converting to CA/RA. Available online: https://sagrainmag.co.za/2022/05/03/financial-benefits-of-converting-to-ca/

Research results: CA adoption

Critical steps to CA adoption:

1. Improve your knowledge about the system, and plan for the change to permanent CA at least 1 year in advance.
2. Analyse your soil (aim for a balanced nutrient and pH status).

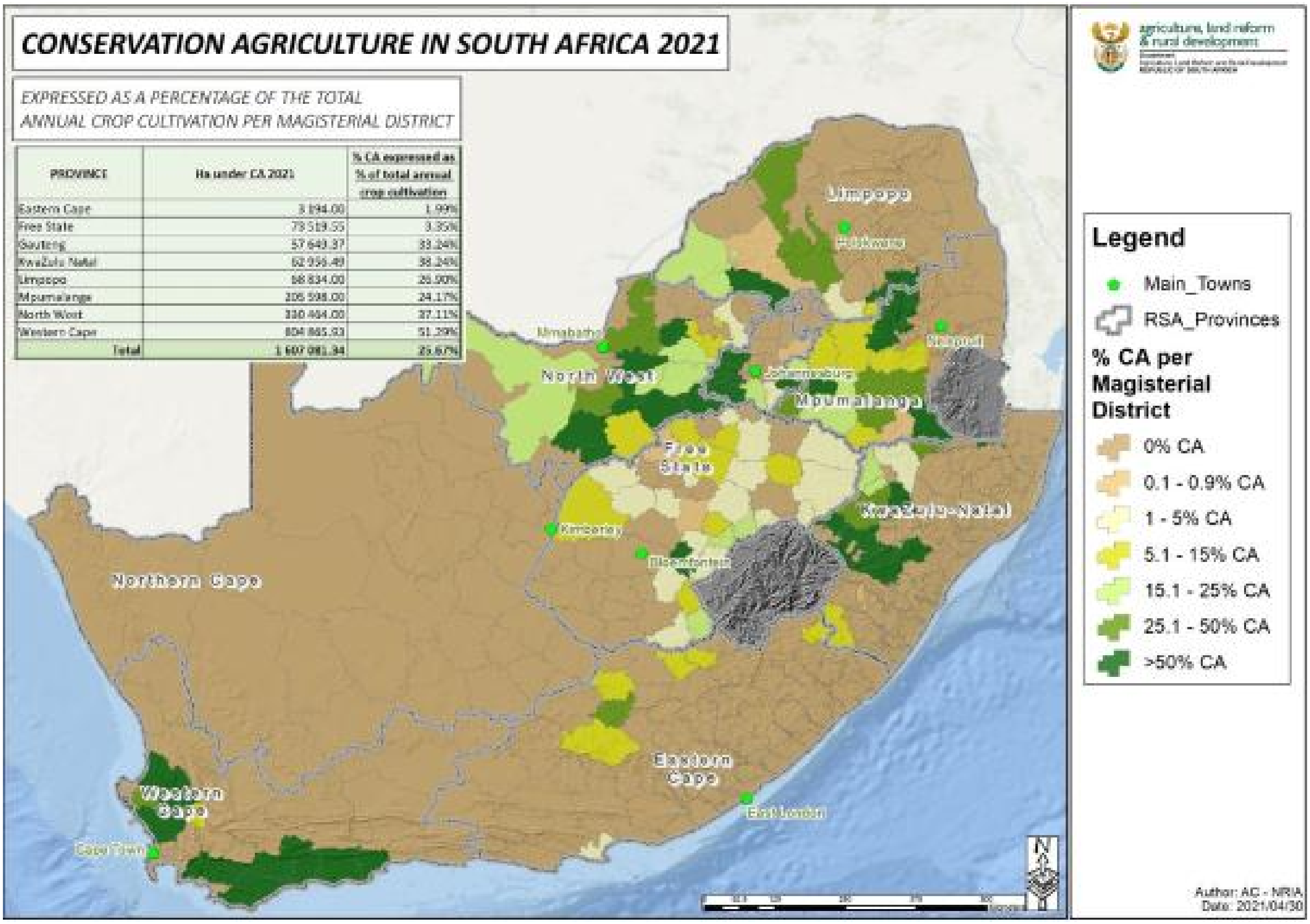
3. Avoid poor soils.
4. Level the soil surface.
5. Eliminate soil compaction and acidity problems before starting CA.
6. Produce the largest possible amount of mulch cover (summer cover crops).
7. Buy a no-till planter and sprayer.
8. Start on 10 % of your farm.
9. Use crop rotations , cover crops and livestock integration.
10. Be prepared to learn and adapt constantly – join the local CA club, or form one.

What practices are followed by grain farmers in SA?

What factors played a role in CA adoption in South Africa? (FAO, 2021)

- Local pioneer CA farmers
- Local farmer groups & research teams working with them
- Local CA equipment manufacturers ('selling the CA system' with equipment)
- International success stories and cross-visits (e.g., to and from Argentina, Australia),
- International pioneer CA farmers (and youtube!) (e.g., Gabe Brown)
- International CA scientist (and youtube!) (e.g., Elain Ingham, Ray Archuleta, Allan Savory, Jonathan Lundgren),
- Local CA scientist,
- Although limited, in some cases there are appropriate support to semi-commercial and smallholder farmers,

- Local service providers and agribusiness (e.g., seed companies).
- Local awareness and information through farmers days, conferences, webinars, popular agricultural magazines and TV channels



PROVINCE	Ha under CA 2021	% CA expressed as % of total annual crop cultivation
Eastern Cape	3 194.00	1.99%
Free State	79 519.55	3.35%
Gauteng	57 649.37	33.24%
KwaZulu Natal	62 956.49	38.24%
Limpopo	68 834.00	26.90%
Mpumalanga	205 598.00	24.17%
North West	330 464.00	37.11%
Western Cape	804 865.93	51.29%
Total	1 607 081.34	25.67%

PROVINCE	TOTAL ANNUAL CROP AREA (HA)	AREA UNDER CA IN 2021 (HA)	CA ADOPTION IN 2021 (%)
Western Cape	1 569 277	804 866	51%
North West	890 437	330 464	37%
Mpumalanga	850 484	205 598	24%
Free State	2 196 986	73 520	3%
KZN	164 620	62 956	38%
Limpopo	255 866	68 834	27%
Gauteng	173 435	57 649	33%
Eastern Cape	160 307	3 194	2%
N- Cape	69 498	0	0%
TOTAL	**6 330 910**	**1 607 081**	**25%**

Resource material

- For CA-FIP information: https://assetresearch.org.za/conservation-agriculture/
- https://restory.co.za/relevant-media/
  (many links in the excel)
- https://www.youtube.com/channel/UCGb27IWUbLmYEhYL7xf7cmg
- https://www.youtube.com/channel/UC-rnKyECFVKuLDgMkHedWZg
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asset research

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