asset research

RESEARCH STRATEGY

CONSERVATION AGRICULTURE

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Basic information – CA research strategy

Title:

Conservation agriculture research strategy

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Overall research goal:
Diagnostic analysis based on scientifically designed trails to determine and compare the changes in the agro-ecological and financial outcomes of different local farming production systems **during both the initial and transitional phases** of converting from conventional to conservation systems.

Overall research question:

Which local farming production system performs the best **during both the initial and transitional phases,** and why, where best is defined in terms of internal and external risk and profitability?

Key research work packages:

1. Soil ecosystem health
2. Agronomy
3. Cover crops and livestock integration
4. Finances

Implementation framework:

5. Identify and select target regions and participants
6. On-farm research
7. M&E
8. Awareness
9. Outreach and decision support
10. Communication

Target regions & farmer structures:

- **Northwest Province:** Ottosdal No-till Club and Mahikeng study groups
- **Eastern and north-eastern Free State:** Ascent (Vrede), Riemland (Reitz) & Maluti CA study groups
- **Mpumalanga Highveld:** The local CA network
- **KwaZulu-Natal & Eastern Cape:** Smallholders learning groups

Production system risk assessment:

- **Internal risk:** Analysing risk under farmer control by means of soil organic matter, water use efficiency, and soil cover.
- **External risk:** Analysing risk not under farmer control by means of exposure to production input costs.
- **Profitability:** Analysing profitability by means of the net margin between revenue (total production sales) and operating expenditure (total production input costs).

Key activities:	Deliverables:	Milestones:	Annual cycle:
Establish scientific collaboratively managed on-farm trials (CMTs)	Well-established and operational CMTs.	Program CMTs successfully established.	Oct-Nov
Execute research as per work packages	Scientific results and analysis of CMTs per work package.	Research reports submitted and reviewed by CA evaluation panel.	Oct-Sept
Farmers days and conferences	At least 1 event per project.	Organised events with farmer structures.	Feb-May
Communication	Various scientific and popular publications.	Publications in relevant outlets.	Oct-Sept

1. EXECUTIVE SUMMARY: CA RESEARCH STRATEGY

The CA research strategy aims to strengthen farmer-centered CA innovation platforms and networks, or **participatory systems research projects,** working with and involving key stakeholders or consortia members, especially farmers, in multi-disciplinary research teams in key summer grain producing regions of South Africa. The purpose is to use these successful projects, platforms and on-farm research sites to reach (scale) out to other target areas and farmers in the regions. The overall research goal is: Diagnostic analysis based on scientifically designed trails to determine and compare the changes in the agro-ecological and financial outcomes of different local farming production systems during the initial and transitional phases of converting from conventional to conservation systems, focusing on summer rainfall regions. The research framework is: 1) Identify and select target regions, research locations and participants; 2) Implement appropriate on-farm research according to needs and priorities identified; 3) Implement a monitoring and evaluation framework and process; 4) Create wider awareness and innovation capacity in the selected study areas and the broader grain production region on the practices and benefits of locally adapted CA systems; 5) Support communication, education, facilitation and reporting.

The approach targets smallholder, semi-commercial and commercial farmers and will as a fundamental principle work directly with key farmer-groups (e.g. study groups and networks), co-workers, and stakeholders, but benefitting all farmers. Well-balanced project teams, using willing and capable collaborators (including farmer co-workers), are created to advance this process as fast as available resources will allow. In that respect new opportunities, partners and resources are continuously identified (e.g., through the CA research forum and wider CA network and collaborators) to facilitate this process; approved projects are then supported through the CA research strategy governance process. Key project activities are on-farm trials and awareness events, sharing information and results through publications, guidelines, videos, conferences and farmers days.

Following an introduction (Section 2) this research strategy therefore comprises the following elements:

- **Why:**

  The question of why CA research is required in South Africa is addressed by providing a rationale (Section 3) as well as an overarching research vision and goal (Section 4).

- **What and when:**

  These questions are addressed by means of the key research focus areas (Section 5) as well as the subsequent research questions, hypotheses & milestones (Section 6).

- **How and where:**

  These questions are addressed by means of a research design (Section 7) and implementation framework (Section 8).

- **Research governance:**

  The research governance is provided by the research oversight and accountability structure (Section 9).

2. INTRODUCTION

This research strategy builds on the comprehensive CA strategy that has been successfully developed, approved and implemented by key stakeholders in the grain industry since 2013 (Smith and Visser, 2014).

As part of a growing body of scientists, practitioners and stakeholders, De Wit *et al.* (2015) argued that conventional (tillage-based) farming systems are not sustainable, expressing the need for more sustainable agricultural production systems. As an alternative to conventional farming systems, Conservation Agriculture (CA) has gained acceptance in many parts of the world (Kassam *et al.*, 2019), as a proven sustainable and cost-effective production system.

CA refers to an agricultural management system based on the simultaneous application of three principles: minimum mechanical soil disturbance, an organic soil cover throughout the year and the use of crop and animal diversity, including crop rotations and associations, as well as livestock integration. These principles enhance natural biological processes above and below ground and involve interventions where soil tillage is reduced to an absolute minimum. The use of external inputs such as agrochemicals and mineral supplements are applied at an optimum level, at quantities and in a manner that does not interfere with or disrupt biological processes. Therefore, CA leads to improved ecosystems' functioning that helps to reduce the use of and dependency on external inputs.

CA constitutes a production system that is not only ecologically sustainable, but also economically feasible and socially acceptable (De Wit *et al.*, 2015; Dumanski *et al.* 2006). CA is based on optimising yields and profits and not maximising yields *per se* whilst exploiting the soil and agro-ecosystem resources (Dumanski *et al.* 2006).

3. THE RATIONALE FOR CA RESEARCH

3.1. Problem statement

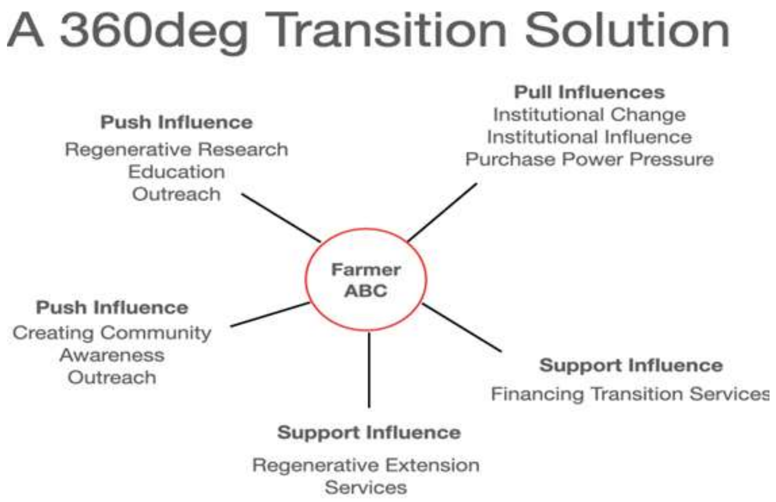
According to literature many environmental problems such as soil degradation, loss of biodiversity and global warming, and their associated socio-economic consequences are caused by, among others, tillage-based crop production practices. These environmental problems (particularly soil degradation through soil erosion and fertility loss and its off-site environmental effects such as sedimentation, siltation and eutrophication of water ways or enhanced flooding) is a threat to the sustainability and profitability of especially grain production. These negative effects of soil degradation pose a threat to food security and eventually poses a risk to national security.

3.2. The unique opportunity being pursued

In order to solve these complex problems, traditional linear research and development (R&D) approaches have proven ineffective and failed completely. Dealing with these urgent and complex problems in agriculture requires engagement with local (on-farm) situations and systems, which requires a different research paradigm. This systems research paradigm is typically one element of a comprehensive "360 degree transition solution" approach to develop and implement sound CA systems in specific target region (see Figure below). This approach must aim to include all the factors influencing and transforming the farmers' context.

This comprehensive approach aims to facilitate and support farmers to make transformational change, and to bridge the so-called J-curve, from traditional conventional tillage systems to CA principles and practices. This transformation process requires critical attention to all the elements of the 360 degree solution, such as human capacity, infrastructure development, capital investments and institutional support.

Following a sound and appropriate **CA research paradigm and strategy** is one of the essential building blocks in such a comprehensive 360 degree approach, and it is up to all key interested role players in the maize industry to make sure all the other elements fall in place helping to accelerate the pace of CA adoption in South Africa.



3.3. An overview of key studies to illustrate work conducted previously

Due to the poor impact of linear R&D approaches (as mentioned above), especially in complex situations, more appropriate and effective approaches and procedures were developed and then formalised in the 1970's (Freire, 1973; Chambers and Jiggins, 1987), but went as far back as the birth and evolvement of CA in the 1950's, driving the innovation process across the world (Coughenour and Chamla, 2000). In South Africa this highly successful CA innovation process, done on farms and by farmers, was recognised as a model to duplicate in the 1980's in KwaZulu-Natal and the Western Cape and was primarily driven by pioneer CA farmers, working with technicians in some cases. This history and success story was well described by Smith et al (2022) and Strauss et al. (2022). These approaches are pragmatically grouped under **participatory systems research approaches**, usually implemented on farm or community level.

Following this systems research philosophy, the CA Farmer Innovation Programme (FIP), funded by the MT for research on maize-based systems, and implemented through Grain SA and later ASSET Research, launched, coordinated and facilitated several successful CA research projects under commercial, semi-commercial and smallholder grain farmers in different summer rainfall regions in South Africa since 2013. This programme's main purpose was specifically to respond to a need or request from CA farmers on the Highveld to make CA research more relevant, since they haven't received any real or direct benefits from the CA research projects running in this area up till that moment (as indicated above). Therefore, the programme's terms of reference was to engage with, support and strengthen the activities of CA farmers on the ground and to reach out to as many other farmers as possible. The philosophy and design of the CA FIP's approach and the implementation of the projects and their activities had to be unique and appropriate to fit the situation created and demanded by the farmers; it also had to join, learn from and support successful local initiatives (such as the Ottosdal No-till Club) as best as possible. The experiences and lessons learned from the CA FIP are very useful for this CA Research strategy. The core message is to start to work with the farmers, build on what they are doing, from where they are. Much more resources, case studies, project reports and references from the CA FIP can be found on the ASSET Research website (https://assetresearch.org.za/conservation-agriculture/).

3.4. Relevance and importance of CA research to the South African maize industry

There is a great need to improve the sustainability (social, economic and environmental) of the maize industry (see *problem statement* above). CA has globally and locally proven to be an ideal vehicle to transform the crop industry towards a much more sustainable regime (Kassam et al., 2019).

This CA research strategy supports adaptive and participatory systems research in CA in South African grain production and is aligned with agricultural policies, conventions and programmes of South Africa, SADC and the United Nations, and specifically supports those developed and adopted during the last decade. Channeling and coordinating funding allocated to CA efficiently and cost-effectively are of prime concern to funding bodies, such as The Maize Trust (MT). Appropriate scientific approaches to on-farm research initiatives are followed to optimize impact and return on investment of adaptive grain crop research in CA.

A description of how the CA research strategy was conceptualized, stakeholders consulted and the envisaged benefits to the industry.

Learning from the CA FIP, the selection of suitable projects has been done according to a range of criteria created around the core philosophy of the CA research strategy (see Box 1), which is used as part of the governance process. To select a potential project study area in a key grain producing region, the presence of an active CA group(s) (farmers are usually organised into structures such as learning or study groups, associations, clubs or cooperatives, of which some focus their efforts on CA) is a prerequisite.

After a CA group is identified in a priority area, such as the Northwest Province, they are approached to start a more formal CA project on a voluntary basis, which is followed by a participatory project proposal development process with the farmers and key stakeholders.

Box 1: CA proposal evaluation criteria

1. Is there a valid research need and research question from the grain producers.
2. Is there a well-defined and -motivated research process and methodology to address the research need and question in participation with a selected group of producers.
3. Addressing key principles and practices of CA
4. Proof of systematic planning and preparation of proposal (technical content and quality).
5. Adequate research framework (goal, objectives, activities, milestones, outputs and outcomes, budget) to implement, monitor, manage and sustain project.
6. Co-funding and collaboration.
7. Demonstrated capacity of the organisation to deliver the project.
8. Feasibility and realism of achieving project objectives (success) within resource allocation.

After a project is submitted and approved, a project team, or also called an innovation platform (IP), is created to launch and implement the project, starting with a participatory planning event from where an iterative adaptive management process followed during a period of at least four years (see Sections below). For smallholders the process is very intense, which require dedicated resources, expertise and support around facilitation, inputs (for small trial plots), infrastructure (no-till planters, sprayers), training and experimentation. Kruger et al. (2021) described how this model was successfully used for implementation, networking and upscaling CA practices and activities in smallholder farming in South Africa under the CA FIP; it has also been promoted nationally as a strategic approach to smallholder adaptation and mitigation programming. The key message is: "Introduction of CA and associated climate-smart agricultural practices within an innovation system approach and using farmer-level experimentation and learning groups as the primary learning and social empowerment processes has created a sustainable and expanding farming alternative for smallholders that is improving their resilience to climate change substantially".

Creating and facilitating these strong and active farmer-centered CA IPs, or research projects across the maize producing regions of South Africa, form the building-blocks of a sustainable and vibrant maize and grain industry. From experiences world-wide and even here in South Africa, these IPs are the best spaces where producers can share and learn better options and experiences towards sustainability.

4. RESEARCH VISION AND GOALS

The **long-term vision of the CA research strategy** is to equip grain farmers with appropriate information, capacity and skills to transform their conventional tillage-based systems to sustainable, resilient and profitable CA systems.

There is thus a need for a long-term research process to study the transition during its initial phases, through its transition (to mature) phase, to analyse and understand the life-cycle impact of the conversion on the different research focus areas or work packages. The table below shows the overall research objective and research question needed to drive the research process during each phase over the long term. The same table is used to guide the formulation of research questions, hypotheses and milestones for each work package in Section 6 below.

Goals	Initial phase: 4 years	Transition phase: 5-8 years
Overall research objective	Diagnostic analysis based on scientifically designed on-farm trials to determine and compare the changes in the agro-ecological and financial outcomes (as described by the work packages below) of different local farming production systems **during the initial phase** of converting from conventional to conservation systems.	Diagnostic analysis based on scientifically designed on-farm trials to determine and compare the changes in the agro-ecological and financial outcomes (as described by the work packages below) of different local farming production systems **during the transitional phase** of converting from conventional to conservation systems.
Overall research question	Which local farming production system performs the best **during the initial phase,** and why, where best is defined in terms of internal and external risk and profitability?	Which local farming production system performs the best **during the transitional phase,** and why, where best is defined in terms of internal and external risk and profitability?

To reach this long-term objective, the CA research strategy employs an implementation framework discussed in Section 8 below. This framework is used to implement approved CA projects and focus areas (or work packages) which are reviewed four (4) years after implementation, or after the initial phase. Recommendations are then made to extend the research into the transitional phase, or to terminate the project.

Research short-term outcomes:

The implementation of the CA research strategy is expected to lead to the achievement of measurable outcomes over the short-term, while medium- to long-term outcomes could be reached in the longer-term and with the wider systems-level elements and support from a comprehensive "360 degree transition solution" approach shown above. These short-term outcomes include:

Short-term outcomes *(directly in reach of research influence)*	**Outcome indicators**
1. Involvement of, growing ownership by, and relationships with critical stakeholders, in CA research and development.	Ownership and leadership by key stakeholders. The strengthening of local CA study groups per area. Improved communication, networking and interaction through different media and structures, platforms.
2. Improved availability of quality research (monitoring) data and evidence.	Research (monitoring) data properly shared and discussed through annual technical reports, popular articles, social media, stakeholder platforms and study groups.
3. An increased level of CA awareness and attitude among producers and other critical stakeholders in the different study areas.	New and innovative CA practices, equipment, data and tools demonstrated and discussed. 100-300 farmers attending awareness events in study areas or regions per year are exposed, influenced and inspired.
4. Enhanced practical/technical and theoretic capacity with respect to CA adaptation and implementation.	Selected farmers/advisors gaining new CA knowledge and skills.
5. An increased level of interest, willingness and courage (motivation) among producers.	Interested farmers are starting to test and adapt CA principles and practices in their own contexts. Using protocols, guidelines and baby trials as key tools.
6. Increased rate and improved quality of adaptation and implementation of CA in the target regions and farms.	Interested farmers able to improve the implementation, adaptation and quality of their CA systems from year 2. Potential impact is big, but it depends on 360 degree support.
7. Improvement in ecosystem health, resilience and carbon footprint, as well as production, efficiency, risk and profitability.	Increases in soil organic carbon; Reduction in GHGs; Reduction in fossil fuel inputs, i.e. N fertilisers and fuel; Improved water use efficiency; Improved nutrient use efficiency; Reduction in wind and water erosion rates; Improvements in biodiversity; Increase or stabilization of production; Reduced risk; Improved profitability

5. RESEARCH FOCUS AREAS (WORK PACKAGES)

The key research focus areas, or work packages, are divided into the following themes, and will subsequently be discussed in detail:

- Soil health and quality,
- Agronomy (diversified cropping systems),
- Integrated pest management,
- Integrated weed management,
- Integrated livestock management,
- Carbon sequestration and climate change,
- Profitability and risk assessment.

5.1. Soil health and quality

Soil is a dynamic living resource whose condition is vital to both the production of food and fibre function. The quality and health of soils determine agricultural sustainability, environmental quality and, as a consequence, of plant, animal and human health. In its broader sense, soil health can be defined as the ability of soil to perform or function according to its potential, and changes over time due to human use and management of natural events. Maintaining and improving the productive capacity of our soils is essential to food security and healthy soils are an essential element of this process. Because the physical and chemical components of soils are largely determined by geographic constraints, the flexibility in soil ecosystems is primarily due to their biological composition and the way they are modified by human inputs (e.g. fertilizers, cultivation and plant species). The role of soil biology, or the soil food web in soils is greatly underestimated and requires increased understanding through research. Establishing the parameters (methodology / standards) of measuring (quantifying) soil health in various production systems is essential.

Integrated soil fertility and acidity management:

A direct impact on soil fertility due to CA is increased soil organic C and N, as well as mineral N (NO_3-N + NH_4-N) because of N fixation, higher N contents of legume residues and N mineralization. Furthermore, the improved soil biological properties will enhance organic matter, nutrient and mineral transformations, thereby favourably affecting soil organic compounds and soil nutrient availability. Soil physical properties such as aggregate stability, bulk density and total porosity are beneficially influenced by residue retention and can indirectly contribute to increased soil biological activity and, consequently, increased soil fertility. It should be emphasized that soil fertility properties like pH, phosphorus and basic cation contents are not directly influenced by a CA practice like crop rotation.

As alternatives to conventional inorganic fertilizers, 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 fertilizers. 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 fertilization, are still contentious fertility issues in a no-tillage CA system.

5.2. Agronomy (diversified cropping systems)

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.

5.3. Integrated pest management (IPM)

Integrated pest management is an ecologically-based approach to pest control combining biological, chemical and other regulatory means. IPM utilizes 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, minimizing 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.

5.4. 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).

5.5. Integrated livestock management

Conservation agriculture practices require a critical level of crop residues and cover crops to maintain or enhance soil chemical, physical and biological properties and prevent land degradation. In many areas of the world, crops and livestock compete for the same resources, and require proper management to meet the objectives of CA. Synergistic integration of crops and livestock offers numerous advantages, but a careful site/crop-specific analysis is needed to quantify conservation and livestock needs. Overgrazing is the most common form of poor pasture management. Ideal management seeks to keep the pasture with full ground cover and always in the productive phase, by adjusting stocking rates or rest periods to avoid over-grazing, and adding fertilizer and lime when necessary (Landers, 2007).

Integrated crop-livestock no-tillage systems allow for further sustainable production of high-yielding pasture without further deforestation (Landers, 2007). Grazing livestock converts both pastures and crop residues into money.

5.6. Carbon sequestration and climate change

Climate change is fast becoming a major international environmental problem. Already in 1997 the Kyoto Protocol was accepted to reduce greenhouse gas (GHG) emissions. With a rise of 0.3°C per decade, sea levels will also rise while the habitat boundaries for many plants and animals will change with disastrous effects on survival. Resource poor farmers in rural areas will be hardest hit by climate change effects because of their limited options to evade risk. Carbon dioxide (CO_2) is the most abundant GHG in the earth's atmosphere, but N_2O is 200-300 times more effective in heating the earth. Where conventional tillage (CT) is the primary driver of accelerating the mineralization of soil organic carbon (C) and nitrogen (N) to release CO_2 and N oxides into the atmosphere, it has been postulated that the implementation of CA practices can act as a potential sink to counterbalance GHG emissions and, consequently, reduce global warming. Diurnal CO_2 evolution was lower under CA maize and soybean than under CT maize. Soil respiration with depth was much lower under CA maize than under CT maize. Seasonal C emission through soil respiration under crops grown with CA practices was lower than under CT maize. Sequestrated soil organic C was much higher (up to 1050 kg C 30mm soil depth^{-1} ha^{-1}) under CA crops than under CT maize. Sequestrated soil organic N was much higher (up to 110 kg N 30mm soil depth^{-1} ha^{-1}) under CA crops than under CT maize.

5.7. Profitability and risk assessments

A clear need was expressed by the maize industry to conduct broader and in-depth studies analysing and comparing the financial performance of CA and other local maize-based farming systems in different regions. Farm inputs, especially fertilizer, chemicals and diesel, became drastically more expensive in the last two growing seasons. The consequences of this rise in input costs and the associated financial risk it implies, are in addition to the consequences of soil degradation and a decline in soil health that requires more external inputs to sustain production yields. It has therefore become increasingly riskier to farm due to dual effect of rising input costs and declining soil health. The effect of this horseshoe pincher is aggravated by South Africa's high variability and fluctuating annual rainfall and -distribution, high evaporation rates, and other natural phenomena such as wind and pests. Combined, these matters do pose a real threat to South Africa's food security and the long-term sustainability of the industry.

While the most used crop performance indicator is yield per hectare, long-term financial sustainability and profitability has gained much prominence in industry role-players. It is therefore no surprise that in recent industry surveys conducted among its producers, that the producers highlighted that their top concerns, threats, and questions are, among others, related to finances, cost reductions, profitability, risks and return on investment.

Research data gathered from on-farm trials provides opportunity to observe the risk structure of each trial and farming system and compare the relative financial performance (profitability) thereof. The risk structure shows a farm's exposure to both internal and external risk. The former being farming system factors that cannot be controlled by farmers such as production input costs since farmers are price takers. The latter being those factors that farmers can control that are detrimental to their soil health such as soil organic matter (SOM), water use efficiency (WUE), and soil cover. The relative financial performance is the net margin between revenue (total production sales) and operating expenditure (total production input costs). These are important variables as the continuity and sustainability of farming operations are significantly dependant on the farm's ability to safeguard its profitability amidst prevailing risk exposure.

The first set of analyses examined the degree of risk exposure of production systems to understand the role of different crop rotation management strategies in aiding and strengthening the adaptive and resilient capacity of farms to better mitigate risk.

6. RESEARCH QUESTIONS, HYPOTHESES AND MILESTONES

6.1. Research questions, hypotheses, and milestones for work packages for commercial farmers

<u>NOTE</u>: It takes time to transform from CT to CA systems, there is thus a need for a <u>long-term research process</u> to study the transition during its initial phases, through its transition to mature phase, to analyse and understand the life-cycle impact of the conversion on agro-ecological and financial outcomes.

Research goals and key work packages	Initial phase: 4 years	Transition phase: 5-8 years
General research objective	Diagnostic analysis based on scientifically designed on-farm trials to determine and compare the changes in the agro-ecological and financial outcomes (as described by the work packages below) of different local farming production systems **<u>during the initial phase</u>** of converting from conventional to conservation systems.	Diagnostic analysis based on scientifically designed on-farm trials to determine and compare the changes in the agro-ecological and financial outcomes (as described by the work packages below) of different local farming production systems **<u>during the transitional phase</u>** of converting from conventional to conservation systems.
Overall research question	Which local farming production system performs the best **<u>during the initial phase,</u>** and why, where best is defined in terms of internal and external risk and	Which local farming production system performs the best **<u>during the transitional phase,</u>** and why, where best is defined in terms of internal and

	profitability?	external risk and profitability?
Soil ecosystem health	**Research question 1:** Does implementing CA increase soil health and fertility across multiple project ecotopes (trial sites) in the various grain regions in this period? **Hypothesis 1:** It is hypothesised that the soil health and fertility status of CA treatments will start to improve soil ecosystems in this period (i.e., increase active carbon and re-establish microbial biomass and activity, start improving organic N levels and availability) and that the CA systems will already provide the greatest soil health benefits with significant variation between different systems and project ecotopes (trials). **Research question 2:** Can nematode-based indices be used to study and predict changes in soil ecosystem health and functioning in croplands under different agricultural management practices and environmental conditions? **Hypothesis 2:** Nematode-based indices represent a reliable toolset for measuring the soil ecosystem health and functioning status of croplands under different agricultural management practices and environmental conditions.	**Research question 1:** Does implementing CA increase soil health and fertility across multiple project ecotopes (trial sites) in the various grain regions in this period? **Hypothesis 1:** It is hypothesised that the soil health and fertility status of CA treatments will significantly improve in this period (i.e., increasing SOM, increasing organic N, P and K availability, resulting in the further decrease of fertilizer use; rebuilding of soil aggregates will be evident) and that the CA systems will provide the greatest soil health benefits with significant variation between different local systems and project ecotopes. **Research question 2:** Can nematode-based indices be used to study and predict changes in soil ecosystem health and functioning in croplands under different agricultural management practices and environmental conditions? **Hypothesis 2:** Nematode-based indices represent a reliable toolset for measuring the soil ecosystem health and functioning status of croplands under different agricultural management practices and environmental conditions.
Cover crops and livestock integration	**Research question 1:** What is the contribution of cover crops and meat production to crop-livestock farming systems in this period? **Hypothesis 1:** Cover crops and livestock CA practices will start to diversify and increase total production (double cropping and income; cash crops and livestock. **Research question 2:** What is the impact of cover crops and livestock integration on soil health and biodiversity and the use of external inputs, especially agro-chemicals? **Hypothesis 2:** Cover crops and livestock CA practices will start to positively affect soil health (see previous work package), biodiversity (e.g., increase in dung beetle activity and pollinators) and the use of external inputs, especially agro-chemicals.	**Research question 1:** What is the contribution of cover crops and meat production to crop-livestock farming systems in this period? **Hypothesis 1:** Cover crops and livestock CA practices will reach much higher diverse total production (through double cropping and income; cash crops and livestock). **Research question 2:** What is the impact of cover crops and livestock integration on soil health and biodiversity and the use of external inputs, especially agro-chemicals? **Hypothesis 2:** Cover crops and livestock CA practices will accelerate soil health (see previous work package), biodiversity (e.g., increase in dung beetle activity and pollinators) and the decrease of external inputs, especially agro-chemicals. **Research question 3:** What is the

	Research question 3: What is the impact of cover crops and livestock integration on production and profitability (biomass, grain, meat)? **Hypothesis 3:** Cover crops and livestock CA practices will start to diversify and increase production and income streams, as well as profitability.	impact of cover crops and livestock integration on production and profitability (biomass, grain, meat)? **Hypothesis 3:** Cover crops and livestock CA practices will significantly diversify and increase production and income streams, as well as profitability.
Agronomy	**Research question 1:** Will CA improve cash crop productivity, quality, efficiency and resilience compared to local CT and NT in this period? **Hypothesis 1:** CA systems will introduce and implement sound cash crop rotations, and start increasing crop residue and soil organic cover, as well a water / nutrient use efficiency. Slight decreases in yields might be expected in some contexts due to poor soil condition and/or challenges to adapt CA correctly, e.g., in weed management.	**Research question 1:** Will CA improve cash crop productivity, quality, efficiency and resilience compared to local CT and NT in this period? **Hypothesis 1:** CA systems will optimise cash crop rotations (e.g., rotating with cover crops and livestock), and will reach much higher levels of crop residue and soil organic cover, as well a water / nutrient use efficiency. No decreases in yields, but instead slight, stable increases are expected, especially in dry / extreme seasons (i.e., improved resilience). Grain and crop quality under CA systems will be better than other local systems.
Finances	**Research question 1:** Does CA implementation reduce the production cost and improve profitability? **Hypothesis 1:** CA does reduce the production cost and increase the profitability of the operations. **Research question 2:** Does the integration of livestock improve the profitability of the operation? **Hypothesis 2:** Livestock integration does improve the profitability of the operation.	**Research question 1:** What are the relative cost differentials, measured in terms of R/ha/ton yield, inclusive of livestock returns, among the various production systems. **Hypothesis 1:** The R/ha/ton yield of CA is higher than that of the comparative systems. **Research question 2:** Does the long-term returns of CA outweigh its initial costs? **Hypothesis 2:** The long-run returns of CA does outweigh its initial costs.
Project milestones		
	Interim milestones are the project reports as per the conventional funding and application cycle of the MT. Final report after 4 years to provide answers to the research questions listed above. Recommendations will be made to extend the research or to terminate project.	Interim milestones are the project reports as per the conventional funding and application cycle of the MT. Final report after 8 years to provide answers to the research questions listed above. Recommendations will be made to extend or terminate project.

6.2. Research questions hypotheses and milestones for smallholder CA research

The overall research question for the smallholder research process is: How will the use of CA improve the production, productivity, environmental and economic sustainability of dryland maize production for smallholder farmers, by focusing on appropriate, adapted localised CA farming systems within a coherent socio-ecological framework, using an innovation systems development approach?

Two sub-groups of smallholders

There are two sub-groups for whom assumptions and hypotheses will differ slightly, given that the CA research strategy will be working with several farmers who have implemented CA for some years already. Smallholders new to CA need a different research emphasis.

Smallholders new to CA: Initial phase, 1-4 years	Smallholders developing an integrated CA system: Transition phase, 5-8 years	Smallholders developing a sustainable, resilient CA system: Mature phase, 4-12 years
Research question 1: How will CA impact the livelihood and profitability of smallholders new to CA in this period? **Hypothesis 1:** CA systems will start to diversify and increase total production (increased maize and legume yields, increased availability of livestock fodder), start increasing crop residue and soil organic cover, start to improve soil ecosystems (i.e. increase active carbon and re-establish microbial biomass and activity, start improving organic N levels and availability) and start to improve water management aspects (decreased runoff, improved infiltration, increased water holding capacity) The **assumption** is that CA will provide for an immediate reduction in input and management costs and show an overall reduction in labour requirements. Participants will become familiar with use of CA practices and implements and start to make arrangements for local access and availability of equipment and inputs.	**Research question 2:** How will an integrated CA systems impact the livelihood and profitability smallholders in this period? **Hypothesis 2:** CA systems will diversify and increase total production (increased maize and legume yields, increased availability of livestock fodder), increase crop residue and soil organic cover, and soil ecosystems functioning under CA systems will accelerate (i.e. increasing SOM, start increasing organic N, P and K (fertility), reduce compaction and rebuilding of soil aggregates); water management aspects will significantly improve (decreased runoff, improved infiltration, increased water holding capacity). Practices for integration of livestock become more of a focus. The **assumption** is that farmers will organize themselves to have access and availability of inputs and equipment and start to consider storage and local marketing options. Farmers will fully master CA practices and implements. They will arrange for local savings and small loan associations to assist in economic sustainability and	**Research question 3:** How will sustainable, resilient CA systems impact the livelihood and profitability smallholders in this period? **Hypothesis 3:** CA systems will diversify and stabilize total production in the context of climate change and weather variability (increased use of suitable and diverse varieties of field crops and increased production of a variety of livestock fodder species), continue to increase and stabilize crop residue and soil organic cover, soil ecosystems functioning under CA systems will stabilize (incl., SOM, organic N, P and K (fertility), reduced compaction and improved soil aggregates). Quantifiable improvements in water management aspects are possible (decreased runoff, increased water holding capacity). Expansion of livestock integration practice and quantifiable improvements in fodder quantity and quality. The **assumption** is that farmers will strengthen their local financial, marketing and collaboration to increase their economic sustainability and will work on the appropriate governance structures

	affordability of inputs and they will improve the social agency of the farmers groups to manage these systems.	in their communities to manage the expanded production and livestock integration aspects. Farmers will fully adapt CA practices and implements in their local contexts.
Milestones		
Interim milestones are the project reports as per the conventional funding and application cycle of the MT. Final report after 4 years to provide answers to the research questions listed above. Recommendations will be made to extend the research or to terminate project.	Interim milestones are the project reports as per the conventional funding and application cycle of the MT. Final report after 8 years to provide answers to the research questions listed above. Recommendations will be made to extend the research or to terminate project.	Interim milestones are the project reports as per the conventional funding and application cycle of the MT. Final report to provide answers to the research questions listed above. Recommendations will be made to extend the research or to terminate project.

7. RESEARCH DESIGN

7.1. Research principles

Important principles emphasized by the CA research strategy are:

- on-farm and farmer-centered (participatory) innovation systems research,
- experiential- and discovery learning,
- continuous interaction and dialogue,
- facilitation and reflection on all levels, as well as
- co-learning, or learning-by-doing.

On-farm experimentation (trials) is a key element of the CA research strategy and has four goals that supports it:

- Generate data on which to assess technology performance under realistic farmer conditions; typically different production systems (i.e. CT, NT and CA) are implemented, compared and analysed.
- Complement the agronomic trial data with farmers' assessments and observations of the adoption potential of technologies. This information helps to understand how the technologies fit into farmers' broader farming and livelihood strategies;
- Encourage farmers to actively participate in trials to stimulate farmer experimentation with, and adoption / adaptation of, new technologies and practices.
- Develop decision-support tools from trial datasets, such as guidelines and protocols to implement certain CA practices and the system overall.

An important and unique perspective from systems research approaches, is that producers are not merely recipients of new knowledge but also potential sources and/or partners in its generation, i.e. they are researchers and innovators in their own right. Local on-farm experimentation, adaptation and ingenuity are vital for finding locally effective practices. The inescapable consequence of this is that farmers function as applied ecologists (scientists) who fine-tune (construct) universal CA principles to their own social, economic, and ecological circumstances or contexts. Accordingly, and at the very least, the emphasis is on on-farm research and the inescapable experiential and discovery learning that this generates; both of which critically place the farmer in the central role.

7.2. Types of on-farm trials

The objectives of on-farm trials are to improve experiential learning, improve understanding and adaptation of technologies to local farmers and conditions, increase awareness among farming communities and facilitate farmer-to-farmer extension. Selener (1998) classified trials conducted on farms according to the level of control and management exercised by farmers and researchers (**Table 1**).

Table 1: Classification of on-farm trials (from Selener, 1998)

HIGHER LEVELS OF OWNERSHIP AND ADAPTATION →	**Collaborative-managed trials (CMTs)** Farmers and researchers work together on problem definition, design, management and implementation of trials as well as evaluation. Ideally, a collaborative relationship means balanced participation in and control over the research process in order to achieve the objectives of both farmers and scientists. Most of the scientific trials implemented and funded under the CA research projects are established in this fashion, and the purpose of these trials is to influence local farmer-level experimentation and adaptation.	**Farmer-managed (-led) trials (FMTs)** Farmers are the main actors and decision-makers in these trials, continuously experimenting, developing and adapting complex technology in their own complex realities. Many farmers will become aware of CA options and start doing their own CA experiments in this fashion. Awareness generally happens through different media (from CMTs, farmers days publications, social media, etc.), at field days, or farmer group meetings or visits.
	Researcher-managed Trials (RMT's) Researcher-managed trials are done on farmers' fields to develop technology for farmers or to test and validate research findings obtained at the research station. Farmers do not participate actively in this process, which leads to very little ownership and adoption.	**Consultative researcher-managed trials** Farmers are consulted at the beginning of the research process to assist researchers in interpreting farmers' circumstances, problems or needs. This leads to experimental designs for trials which often will not include farmer participation at the initial (i.e. planning and design) stages of on-farm testing. Technology is developed for farmers based on the researchers' understanding of their farming systems, which leads to very little ownership and adoption.
HIGHER LEVEL OF PARTICIPATION, LEARNING AND UNDERSTANDING BY FARMERS →		

8. IMPLEMENTATION FRAMEWORK FOR CA RESEARCH

8.1. Identify and select target regions, research locations and participants

1. Use appropriate agro-ecological delineations, or key summer grain (maize) producing regions as basis to select specific study area(s). The broad regions demarcated in Figure 1 below are: Northwest Province, northwest Free State, eastern- and northeastern Free State, Mpumalanga Highveld, KwaZulu-Natal and Eastern Cape. The latter two provinces have a high percentage of smallholder farmers in need of CA support.

Figure 1: Demarcation of the key maize producing areas of South Africa (from BFAP, 2015)

2. Identify and engage with active and interested farmer groups (volunteering, where there is a demand) as platform(s) for implementation.

   Since 2013 various CA research projects have been implemented in these regions, namely:

   - Northwest Province – Ottosdal No-till Club and Mahikeng study group
   - Eastern- and northeastern Free State – Ascent (Vrede), Riemland (Reitz) and Maluti study groups and networks
   - Mpumalanga Highveld CA network
   - KwaZulu-Natal and Eastern Cape – smallholder learning groups under Mahlathini Development Foundation

3. Facilitate a participatory diagnosis (of problems, challenges, etc.) and planning process with farmer groups and other key stakeholders.
4. Identify research locations on specific farms and ecotopes for CMTs.

8.2. Implement relevant on-farm trials according to needs identified

1. To implement CMTs, the following elements are required:
   - Research question(s);
   - Hypothesis, which is your expected outcome of the trial and why you (farmers and scientists) collectively think that way;
   - testing the hypothesis. That means doing the experiment or treatments, that is, variations to the normal procedure;
   - A control, which is what the farmer normally does - this control must always be included to compare or check against any treatment;
   - A design, that is, where treatments are positioned in the field and in relation to each other- the design is very important and may be the difference between obtaining an answer or not;
   - Measurements and recording of effects (results) - these give the trial objectivity and show how big the effects are (see M&E and indicators below);
   - Measurements (monitoring) and reporting must be done systematically and scientifically (technically correct).

   NOTE: A CMT that is not carried out properly is often worthless and wastes a lot of scarce resources. It may seem to give an answer though the answer may in fact be quite wrong. If forward planning or changed farming practice is based on that wrong answer, the farmer could lose income on future crops. No trial is preferable to a bad trial. Consultations with statisticians are done while the trials are designed. Screening trials and simple comparisons could also be considered and used for demonstration and awareness purposes.

2. Where Farmer-managed trials (FMTs) are considered, they should be implemented parallel to CMTs, or without the existence of CMTs in many situations (as in reality CMTs will only be established if required / needed and where sufficient resources (i.e. funding and capacity, which include suitable farmer- and researcher co-workers) are present), many CA treatments and changes (adaptations) are too complex and dynamic (e.g. cover crops x livestock x grazing integration) to be included in CMTs and would only be possible to test and adapt through FMTs.

8.3. Implement a monitoring and evaluation framework and process

1. **Monitor trials and collect data.** Monitoring of on-farm trials and analysis of the data collected (social, economic and biophysical) is part of the research process. Appropriate indicators should be measured and monitored to track changes and influence decisions on CA system adaptation. Farmers, extensionists and researchers, should visit the individual CMT and FMT sites as frequently as possible and observe, compare, analyse and discuss results and the differences between individual farmers – the main aim is to identify and evaluate opportunities for improving / adapting their own management. Subject matter specialists

(researchers) should assist with technical monitoring, data management, (statistical) analyses, interpretation and reporting where possible and necessary, especially with CMTs. Farmer observations, experiences and reflections, as part of participatory monitoring and evaluation (PM&E), are essential in FMTs.

2. **Evaluate impact.** The trial results of possible solutions should be evaluated on the basis of whether they are technically, socially, economically and environmentally acceptable at the farm household level. In the case of environmental aspects, they should also be acceptable to the community at large.

8.4. Outreach and decision support

1. Plan and organise field and farmers days, conferences, to demonstrate, share and discuss the trials, activities and results with key stakeholders.

2. Produce decision-support tools, risk assessments, guidelines and protocols from trial data to assist farmers to implement local CA systems. However, a consequence of the uniqueness of each farm, is the fact that systems research cannot generate custom-made 'one-size fits all' solutions and recipes for every reality.

   The idea is to develop a ‘living CA Manual’ (or standard operational procedures, guideline and protocol; to be submitted as a separate new application), which will *inter alia* include the following:

   - Taking account of all lessons learned – past and as we go.
   - Influenced by research results from completed CA research projects.
   - Broad framework and guideline.
   - Emphasis on the ‘HOW TO’.
   - Context and/or region sensitive.
   - For: Beginner farmers (e.g. how to start?).
   - For: Pioneer, advanced farmers (e.g. how to integrate livestock?).
   - Financials included.
   - Using multimedia – articles, social media, videos, etc.

3. Strengthen the role and functioning of local CA structures, such as study groups, networks, etc.

9. THE MANAGEMENT OF MAIZE TRUST CA RESEARCH GRANTS

9.1. CA research governance process

After publicising of CA funding opportunity to interested applicants, the application process for funds is initiated through a call for proposals. This kick-starts the process of proposal development, submission and review. Proposals will be reviewed by a panel of experts on the various themes or topics included in the proposals (see Box 1 for evaluation criteria). The whole process will be administered by The Maize Trust administrators in cooperation with a convener of the CA evaluation panel through following steps:

1. Call for research applications (closing date 30 September for new proposals, and 31 March continuation proposals)
2. Trust administrators (currently Agri Manage Solutions) send proposals received to convener of CA review panel.
3. Convenor sends out proposals to external reviewers with evaluation criteria. The evaluation of a new proposal has from October to April (the following year) to complete the process, while continuation proposals have from the end of April to August to be approved by the Trust and ready for continuation in September that same year.
4. The CA evaluation panel review, score and make recommendations of all project applications (new and continuations) as well as biannual (March) and annual (September) progress reports using existing criteria for project proposals and progress reports.
5. The CA panel convener presents evaluation results and recommendations to the Maize Forum Steering Committee (MFSC) and finally MT trustees.
6. Trust administrators informs successful applicants around July / August.

The above process encourages, allows or aims to match-make applicants (researchers, NGO's, brokers, etc.) with interested farmers to design projects together, and involves other farmers alongside scientists in reviewing research proposals (i.e. as members of the reference group). This extended review process in no way dumbs down the science – the winning research will need to be top-notch scientifically (either natural and/or social sciences) and practically relevant to people at the sharp end, especially being guided by the CA research strategy objectives and criteria.

9.2. CA research forum

An annual CA research forum is organised by the CA convener, or Trust administrators. The CA research forum's purpose is to provide the various project opportunity to present the annual report and to allow robust reflection, interaction, and review and to assist the CA evaluation panel in monitoring progress and evaluating deliverables. The CA research forum is only required to act in an advisory capacity.

CA research forum meetings are scheduled annually (or more frequently, if required) with the CA project teams in attendance and the CA facilitator and/or convener, or Trust administrators fulfilling the role of organiser. Progress reports for the preceding period and work programmes for the following cycle are tabled at these meetings.

Powers and functions of the CA research forum

- To assist and guide the project teams in achieving the objectives of the project as embodied in the CA research strategy and to recommend and authorize a change of emphasis in respect of the methodology to be followed where considered necessary.
- To meet at least once a year in order to evaluate Progress Reports and Proposed Work Programmes, bearing in mind:
    - the objectives, research questions, hypotheses and milestones as proposed, and
    - the duration and progress of the project.
- To invite CA panel members to the CA research forum to evaluate the annual reports presented and new proposals using existing criteria, and to make a recommendation to the Trust.
- To co-opt or invite additional members to the CA research forum, especially farmers and researchers / scientists.
- To consider requests for project extensions relating to time and funding and make appropriate recommendations to the Trust.

Although the CA research forum cannot alter the aims of the project, changes in approach can be recommended. However, group members should be sensitive to the budgetary implications of any recommended changes to the project.

9.3. Reporting

Reporting requirements for CA projects are:

- a biannual progress report by end of March,
- an annual progress report by end of September,
- a final report after project completion.

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