ASSESSING THE IMPACT OF CONSERVATION AGRICULTURE PRACTICES ON WHEAT PRODUCTION IN THE WESTERN CAPE

REPORT FOR

**ARC-Small Grain Institute and
the Western Cape Department of Agriculture**

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EXECUTIVE SUMMARY

Conservation agriculture (CA) practice consists of three main elements: minimum soil disturbance, maximum soil cover and crop rotation. These can be applied individually or together and at the same time. A comprehensive impact study was undertaken to assess the impact of CA practices among wheat farmers in the Western Cape Province. Farmers were introduced to the CA farming system by a combined ARC, Provincial Department of Agriculture effort, in collaboration with officials from other institutions.

Wheat is by far the biggest winter cereal crop planted in South Africa. Other winter crops are barley for malting purposes and canola. The three main wheat producing provinces are the Western Cape (winter rainfall), Free State (summer rainfall) and the Northern Cape (irrigation). Production in South Africa is not sufficient for domestic requirements and the country has to import wheat to meet its domestic demand.

Wheat farmers of the Western Cape traditionally planted wheat commercially using a monoculture system, but many of them have now adopted CA. The CA technology is regarded as an innovative approach for improving resource use in an integrated management system. Western Cape farmers have adopted a range of production techniques and this study seeks to establish the impact that resulted through the adoption of these technologies.

Fifty-one farmers who had adopted CA were interviewed by Western Cape Department of Agriculture officials using an ARC developed questionnaire. Data was captured and analysed by ARC officials. During data analysis the assigned economist discovered limitations that originated from incomplete data collected during the survey. These data limitations related to the quantitative data and this affected the extent to which analyses could be carried out.

The results from the survey broadly illustrated a positive technology impact with many benefits linked to soil health. The technology has also affected productivity and income in a positive way. Negative impacts relate to capital expenditure (equipment costs). Best practices of CA are compatible with large and small farms' operations, indicating the versatility of the technology.

After the preliminary results were presented to the Western Cape Department of Agriculture it was resolved that additional data would be sourced. The data was sourced from the Departments' experimental farms and from GrainSA. The quality of the report was subsequently improved with a counterfactual scenario that allowed for comparison with the CA technology adoption and gave an improved estimation of the effects of the technology. The study determined production costs for both conventional tillage and no-till, for continuous monoculture wheat production. In the 2009/10 production year it was found that it cost 46.3% more to produce the same amount of wheat per hectare with a conventional system than with CA technology.

The study further presented gross margins from crop rotation systems practiced at the experimental farm. The crop sequences included wheat as a main crop, rotated with clover, lupin, medic plant and canola. The lowest gross margins were recorded for the wheat monoculture system while the highest gross

margins were recorded for the pasture-based systems (e.g. wheat rotated with clover/medic). The study also attempted to assess the impact of R&D investment in CA technology as it applied to the Western Cape wheat farmers. Data on farmers' conventional wheat yields were compared with those that come from researcher CA trials. This would enable the ARC researchers and other stakeholders to be able to trace the R&D contribution to the uptake of CA and the subsequent improved performance on CA production systems.

The success of conservation agriculture depended on the flexibility and creativity of its practitioners as well as the quality extension and research services provided. The fact that wheat farmers adopted a conservation agricultural system with the proper training and support attests that the system is sustainable. Furthermore all stakeholders were committed to the farming system, not just a one farming method. It was also found that R&D applied through collaborative efforts of different stakeholders (such as in this case, where the Western Cape Department of Agriculture and the ARC complement each other's expertise) stands a better chance of success.

1. STUDY BACKGROUND

The adoption of soil conservation principles has the potential to play an important role in increasing agricultural productivity. Conservation Agriculture (CA) combines the best known traditional and modern practices to manage soil, water and agriculture. CA in general includes three major principles: minimum soil disturbance, maximum soil cover and crop rotation.

A comprehensive impact study was undertaken to assess the application of CA practices among grain farmers in the Western Cape Province. The use of CA in the Western Cape's grain production areas has escalated from less than 5% in 2000 to about 60% in 2010 (Tolmay, 2011). Farmers were introduced to the CA farming system through a combined ARC, Provincial Department of Agriculture effort, in collaboration with officials from other institutions, which led to a spectacular rate of adoption of CA. The ARC researchers participated in research on general production practices such as seeding densities, row width and fertiliser placement under CA conditions. The work of Dr Mark Hardy of the Western Cape Department of Agriculture who strongly promoted the use of crop rotation in the region, also made an invaluable contribution.

The adoption of CA in the region was also made possible by the simultaneous development of robust no-till planters which were able to plant in the stony soils of the region. Other technologies introduced included the use of pre-plant herbicides (trifluralin) in order to control herbicide resistant ryegrass. Most of these technologies originated in Australia (with similar climatic conditions) and the basic task of the researchers and officials was to adapt these technologies for local use.

The process was initially used by only a few brave farmers who continued to believe in the system despite early setbacks. Once CA appeared to be working, many other wheat farmers followed. The farmers involved in the study are all wheat farmers who have adopted CA, for different reasons including it being perceived as the best farming practice, ease of management, risk reduction and economic motives. Farmers primarily adopted CA technology to offset exorbitant production costs and to remain profitable in wheat farming (see conventional production costs in tables 3 and 4). South Africa is currently importing roughly half of its wheat and a significant fraction of the country's consumption will continue to be met by imports. Hence any technology that will encourage growth in local wheat production is welcome. The CA technology and the introduction of new seed varieties can result in long-term growth thereby curbing the outlook presented by the table below, projected from a BMI[1] report:

Table1: South Africa Wheat Production & Consumption, 2011-2016 ('000 tons)

	2011	2012	2013	2014	2015	2016
Wheat Production	1,511.0	1,842.0	1,915.2	1,948.3	1,971.0	2,035.6
Wheat Consumption	2,956.7	2,992.2	3,032.6	3,108.5	3,186.3	3,266.1

[1] Business Monitor International: Agribusiness Q1 2012

As seen in table 1, South Africa will continue to import wheat to cover its deficit as less wheat is produced than consumed. Low wheat prices, high input costs, unfavorable weather conditions, and standards set by the liberation of the market, which rule the South Africa agricultural sector since the end of 1997, resulted in wheat production decreasing drastically. Thus, wheat research is becoming increasingly important to aid farmers in producing a cost-effective crop. CA is an innovative approach for improving resource use through an integrated management approach. There is apparently an economic rationale for promoting conservation agriculture among grain farmers and wheat farmers in particular.

New wheat varieties are developed and released to improve wheat yields, pest resistance and grain quality. The ARC-Small Grain Institute has traditionally been at the forefront of public varietal improvement research. Today private sector companies are dominating in terms of market share. Stander (2012) described wheat yield growth in South Africa. He illustrated that during the 1970s yield increased by 27% while from 1980 until 1990 yields increased by 19%. From 2000 until 2008 yields increased by 11%. Stander (2012) explained that wheat yield growth can mostly be attributed to two factors; yield improvement through breeding; and through improved wheat production/farm management practices. The impact of breeding led to huge increases but management issues also played a significant part. For instance, as farmers implemented moisture conservation in the dry land production areas and farmers in the irrigated areas moved away from flood irrigation to pivot irrigation, yields increased.

Stander (2012) further explained that it was during the 1990s that the deregulation of South African Agricultural sector (which included abolishment of the Wheat Board) resulted in farmers becoming more efficient. This too led to private wheat breeders becoming more competitive in varietal improvement and resulted in R&D in varieties shifting from public breeders to the private sector.

The situation in the wheat industry indicates that if wheat production is to remain significant in South Africa, continued improvement in yields will be needed. The country's wheat producers should be assisted in improving their yields through use of better seed varieties and improved farming systems including through the application of innovative systems such as CA.

2. STUDY OBJECTIVES

Broadly the study attempts to show how adoption of CA technology had impacted on the wheat farming community of the Western Cape Province. Specifically, the impact assessment study indicates:

1. How much land is under CA as opposed to conventional systems.
2. Adoption stages of CA.
3. The main driving forces for adoption.
4. Impacts resulting from CA adoption in terms of profitability, sustainability, environmental impact (soil health), livestock production etc.
5. Return on investment in research funding

3. DESCRIPTION OF THE STUDY AREA

The study investigated wheat producing farmers in two different agro ecological climatic zones in the Western Cape Province namely, the Swartland and Southern Cape. The Western Cape (winter rainfall) together with the Free State (summer rainfall) and the Northern Cape (irrigation) are the three main wheat producing provinces. According to the wheat production guidelines report (2010), wheat is planted between mid-April and mid-June in the winter rainfall areas (Western and Southern Cape). The Crop Estimates Committee (CEC) report of July 2013 indicated that the area planted to wheat in South Africa was 511 200 ha in the 2012/13 season. In the Western Cape, 272 000 ha of wheat was planted while 84 940 ha was planted to malting barley and 44 100 ha planted to canola.

The area planted to wheat in the province has decreased over the last 15 years since the emergence of a free market economy (Strauss, 2012). Before the introduction of CA technology, farmers were producing wheat under a monoculture system. The adoption of CA has brought about a wide range of crop rotation systems in the Western Cape production area. Strauss (2012) explains that for the Swartland area the rotation systems are mostly 4 year rotations. Examples are wheat-lupin-wheat-canola (thus 50% of farm planted to wheat, 25% canola, 25% lupin), wheat medics-wheat-medics (50% planted to pasture and 50% planted to wheat), while in the Southern Cape long and short rotations are used. Short rotations are very similar to the Swartland, while the long rotations consist of 5-6 years of permanent lucerne followed by 5 to 6 years of cash crops. An example will be: lucerne-lucerne-lucerne-lucerne-lucerne-lucerne-wheat-barley-canola-wheat barley-lupin (thus 50% of the farm will be planted to pasture, 16% to wheat, 16% to barley, 9% canola and 9% to lupin. These percentages of crops on a specific farm vary hugely depending on the farming area and the farmer.

4. DETAILED DESCRIPTION OF THE CA TECHNOLOGY

The section presents a detailed description of the three components of CA:

Minimum soil disturbance: The critical component of conservation tillage is the minimization of soil disturbances. Reduced (minimum) tillage is a tilling practice with minimum plowing frequency as compared to conventional tillage (Darby, 2011). Instead of conventional ploughing and sowing, the seed and fertilizer are sowed directly in the stubble of the previous crop. This is done with an implement with steel teeth or blades instead of traditional ploughshares. The teeth makes a furrow in the soil, into which the seed and fertilizer is placed. The furrow closes upon itself after the tooth has moved on. No-till prevents degradation of soil structure since the soil is not ploughed and pulverized.

Maximum soil cover: This includes retention of plant stubble. If the stubble is retained, it prevents soil erosion by wind and water. It also lowers soil temperature, preventing the destruction of bio-organisms in the soil. The stubble also limits evaporation of the moisture in the soil, which stimulates the degradation of organic material in the soil, and has an enriching effect.

Diversified crop rotation: Crop rotation refers to the cultivation of different crops alternating on a specific piece of land; the same crop will not be cultivated every year. By rotating crops the soil will not be exhausted and gets the opportunity to recover (Western Cape Department of Agriculture, 2009).

Ideally all three principles of conservation agriculture should be applied simultaneously. Certain proponents of CA view minimum inorganic input as a fourth principle of the approach.

5. LITERATURE REGARDING CA TECHNOLOGY

Literature showed that CA technology has become integrated into many farmers' activities both in this country and abroad. This section covers a few studies that explored CA technology on maize and wheat:

BFAP (2007) undertook a research project which described economic and biological aspects pertaining to the adoption of CA. The study was conducted among maize farmers in the North West Province. The study also drew from studies across the globe including that of the Food and Agriculture Organization and showed how production variables are affected in the first few years after adopting CA. The BFAP study reported that yield decreased temporarily during the first phase after adoption, gradually increasing in the later phases. The first phase includes familiarisation with the approach and adaptations by the farmer. The report stated that such a process includes mistakes and inefficiencies that inevitably occurred in the early days before a farmer became more familiar with the techniques, improve his or her practices and management, and learn from previous mistakes. The second phase is where the biophysical environment's natural balance is restored. The study concluded that with appropriate research and extension, CA has the potential to replace existing conventional practices without impairing farm productivity.

Du Toit and Mashao (2010) stated that a significant shift towards CA will necessitate intervention at two levels: firstly, tangible involvement of agribusiness, especially in developing equipment and secondly, the on-farm evaluation of CA in close participation with farmers. Du Toit and Mashao (2010) also stated that although farmers indicated that they were aware of the advantages of CA, they tend to focus on obstacles and challenges ahead. Generally before the farmers adopt a technology, they think of the risk of decline in a yield at the early stages of changing from an old to a new system. Conradie (2012) confirmed this by sharing his experience with a shift from conventional farming to a CA system. He however gave his observations based on maize production on nine farms in Mpumalanga. While the introduction of CA can result in crop yield benefits in the long term, in the short term yield losses or no yield benefits are just as likely (Giller *et al.*, 2009). It is during the transition time that farmers need support. A continuous interaction among farmer support groups and stakeholders becomes relevant and appropriate to maximize R&D outputs and outcomes.

The ARC-ISCW has been involved with global and regional FAO leadership and national institutions to develop a standard, adaptable CA Poster[2] that could be used for initiation and implementation of CA

[2] http//posters.ecoport.org (poster serial number no.8455)

awareness campaigns. The poster has a “standard CA message”. The poster explains the elements of CA and the implementation of CA principles. It concludes by listing the major benefits of CA in terms of financial, agronomic, and environmental benefits. The major financial benefits of CA included less input costs and savings of time and labour; reduced costs for fuel maintenance of machines; and more earnings through both cost reduction and increased income.

A study from the FAO document repository of 2007 gave a world view of conservation agriculture and the economics thereof. This FAO report indicated that conservation agriculture was at the time practiced on about 57 million ha, or on about 3% of the 1 500 million ha of arable land worldwide. Most of the land under CA is in North and South America. It is rapidly expanding on small and large farms in South America, where farmers are highly organized in local, regional and national farmers' organizations. In Europe, the European Conservation Agricultural Federation, a regional lobby group, unites national CA associations in the United Kingdom, France, Germany, Italy, Portugal and Spain. Despite these advantages, CA has spread relatively slowly, especially in farming systems in temperate climates. The study indicated that transformation from conventional agriculture to CA seems to require considerable farmer management skills and involves investment in new equipment. It further argued that it may also require minimum levels of social capital to foster CA expansion.

The FAO study further identified and analysed the financial and other conditions that serve as an incentive for farmers to adopt CA practices. It reviewed the literature and analysed the economics of technology adoption at farm level. It identified divergences between privately appropriable benefits and national or global economic benefits stemming from an expansion of the area under CA. It also examined the policies and options for bridging these, particularly in the light of the current policy setting in both developed and developing countries. One of the conclusions is the cost advantage over conventional practice in general terms.

A study conducted by Epplin *et al* (2005) in Oklahoma city determined production costs and economies of size for both conventional tillage and no-till wheat production. The study compared the number and type of field operations (tillage, seeding, herbicide application, insecticide application, fertilizer application, and harvest) for both conventional tillage and no-till production systems. The study showed that no-till required more herbicide, custom application, and total operating costs. Conventional tillage required more fuel, lubrication, and repairs, and more machinery fixed costs. It concluded that no-till has not been more economical than conventional tillage for continuous monoculture wheat in the region. This conclusion should be considered only in the light that the comparison was based on different farm sizes and it disregarded yield differentials. The major limitation of this study was that yield differences and thus revenue had not been considered.

The studies reviewed confirmed CA adoption locally and internationally. They verified that in the process of the adoption, farmers needed continuous interaction with support groups and stakeholders. In most studies production costs were compared with accruing benefits to demonstrate a favourable relationship between the two. Some studies advised that the CA benefits should be assessed carefully as some benefits could not be captured with conventional techniques that are limited to financial terms.

6. METHODOLOGY

This section presents the methodology used as well as an explanation of the processes involved and some of the difficulties encountered.

Hundred questionnaires were mailed to wheat farmers in the Western Cape Province, which resulted in three responses. The total number (100) was regarded as a good statistical representation of the CA wheat farmers in province. A second attempt to obtain farmers' participation in the survey was through personal interviews. Forty-eight (48) wheat farmers were interviewed which brought the total number of completed questionnaires to fifty one (51). Whilst it became clear that the data collected through the questionnaire, in retrospect, was not sufficient to capture the impact of the CA intervention, it was nonetheless processed and an interim report was produced. A meeting was subsequently organized with the Western Cape's Provincial Department officials to discuss the interim results and it was resolved that additional quantitative data would be availed to improve the report.

6.1 ADJUSTMENT TO THE SURVEY

Additional Western Cape wheat data for conventional and CA farming system was sourced from Grain SA and CA farm trials managed by the Department's officials. The data enhanced the impact assessment and enabled a computation of R&D effects on CA adoption as the 'with' and 'without' technology scenarios were constructed. Data on wheat production under the CA approach was used to develop a 'with' scenario while the production with conventional farming system was used as the 'without' scenario. The 'with' scenario describes outputs and outcomes under CA (the factual) which were compared with the outputs and outcomes for the 'without' or conventional scenario (the counterfactual) to determine the impact of the CA intervention. The aim was to identify the changes in outcome that are directly attributable to the intervention.

6.2 QUESTIONNAIRE DESIGN AND SURVEY PROCEDURE

The questionnaire used in the study was developed in consultation with the ARC-Small Grain Institute researchers, officials from the Western Cape Department of Agriculture, statisticians and economists in the ARC Economic and Biometrical services division and other professionals working in the field of wheat farming and CA technology. The questionnaire aimed to gather information about the community and household characteristics which would assist in the appraisal of CA. It was designed with the intention of analyzing predominantly quantitative results using SAS Software. The use of this analysis programme required that most questions be designed as closed questions with identifiable coded options. The questionnaire has been included as appendix A. Interviews were led by the officials from the Western Cape Department of Agriculture. The officers were familiar with the area, cultural intricacies and the local language. Although the option of having ARC economists conducting the interviews with the Department's officials would have been ideal, the presence of outsiders in the interviews would possibly have had a noticeable effect on the interviewees. They were likely to be unsettled by the outsider's presence and their answers or co-operation could have been affected.

7. SURVEY DATA ANALYSIS AND RESULTS

7.1. DATA STRUCTURING AND SOFTWARE USE

Once the data was captured through the survey, Microsoft Excel spreadsheets were used to capture the information from the questionnaires. Both SAS Software and Microsoft Excel were used in analysis. Predominantly frequency analysis and descriptive statistics were used in the analysis of question responses and the results were presented in SAS output format (Appendix B) and excel graphs (Appendix C). Specific answers were identified as being potentially unreliable. After seeking advice from a statistician, it was decided that these questionnaires would not be withdrawn from the data pool but be used and interpreted with caution. Incompleteness may have been as a result of an uninterested interviewee, and possibly a hurried interview.

7.2 DISCUSSION OF THE SURVEY RESULTS

This study presents the results of interviews with 51 wheat farmers with the aim to determine the impact of CA technology on their farming systems. The descriptive analysis of the data revealed that 49% of the respondents were practicing all three components of CA, followed by 29.4% who practice only minimum tillage. Thirty nine percent of the respondents heard about the CA technology from other farmers. The dominant age of the farmers was between 31 and 50 years. It could be inferred that middle aged farmers were more active in adopting CA. Most respondents have as their highest level of education an agricultural diploma or agricultural degree at 39.5% and 37.3% respectively.

A four factorial analysis variance was performed on the variable farm size (hectares). The factors involved included age, level of education and level of farming experience prior to adopting CA farming practice.

The mean farm under CA was 1089.3 ha whilst the average hectares under conventional agriculture were 107.5. It implied that CA farms were roughly 10 times larger than conventional farms. It was found that there was a significant (at 5% significance) difference between farm size and age group (probability=0.039). This implied that age had a positive effect on the use of land.

A combination of benefits such as increased total yield, increased quality and improved weed management was perceived by 25% of the respondents as the result of using CA technology. The main reason for engaging in CA farming practice was cited by 28.3% of respondents as it being the best farming practice, followed by a combination of reasons including, 'best' farming practice and reduced risks at 15.2%[3]. These responses are in line with findings in a quantitative analysis which indicated that it was more costly to produce wheat through conventional technology.

The data also revealed that the impact of CA adoption has resulted in increased specialized equipment prizes and increased weed and pest control costs. Probably the most important finding was that farmers

[3] Note that this question was responded to by 46 out of 51 respondents.

perceived that CA has resulted in increased income/ha and overall income. Improved water quality, reduced labour and fertilizer costs were also recorded.

Eighty-one percent (81%) of respondents considered the application of CA as relatively easy and 97.9% felt that CA technology uptake was growing. Sixty-four percent (64%) of respondents had recently purchased specialized equipment for their reduced tillage practice. Notably, the first specialized CA equipment was introduced by the ARC-SGI.

Unfortunately, 70% of the respondents to the survey did not provide data on wheat yields under CA technology. Where wheat yield per hectare was provided, the specific year in which the yield was achieved, was not given. This lack of quantitative data curtailed financial analysis that would enable the calculation of return on investment. This limitation was subsequently corrected by obtaining data from agricultural institutions in the Western Cape which have records for these farmers affiliated to them.

This study also determined production costs for both conventional tillage and no-till for continuous monoculture wheat production. In the 2009/10 production year it was found that it cost 46.3% more to produce the same amount of wheat per hectare with conventional system than with CA technology.

7.3. CATEGORIES OF FARMERS

According to Rogers (1995) technology adoption can be described in terms of categories of adopters with Innovators often being the first individuals to adopt an innovation). So called early adopters are followed by the so called early majority. These individuals adopt an innovation after some period of consideration. Hereafter the so called late majority adopt the technology - after the average member of the society under scrutiny has adopted the technology. Laggards, the individuals that are the last to adopt an innovation, are the last category. Although the level of adoption was not directly addressed in the survey, respondents were requested to indicate which of the three elements of CA they had adopted. This was used to develop a categorization of CA adopters, indicated in figure 1:

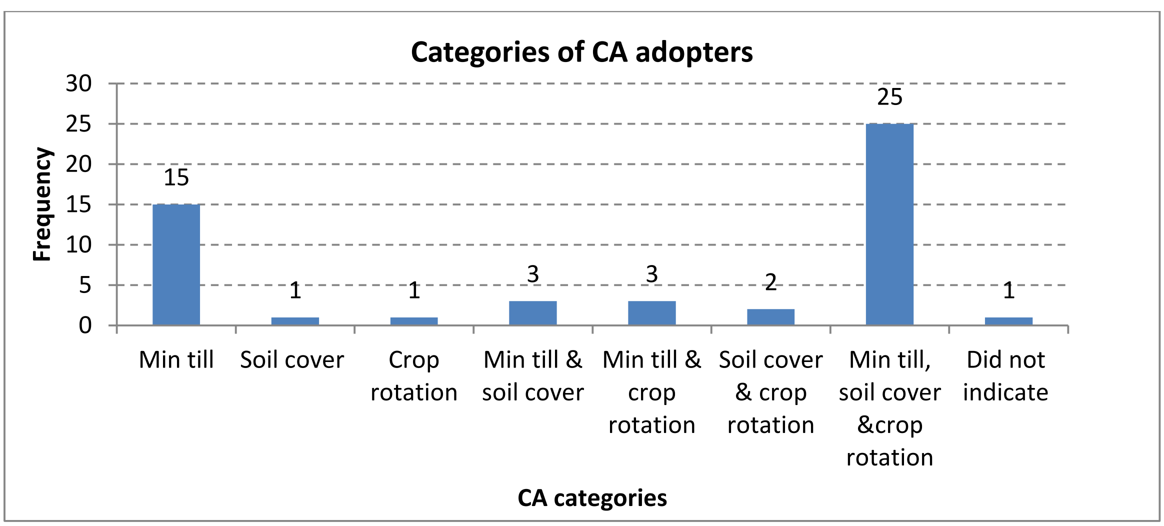

Figure 1: Categories of CA adopters

Although the sample size was limiting, it is nevertheless important to note that the biggest group, making up 49% of the respondents was practicing all three components of CA, followed by 29.4% who practice only minimum tillage. These results also constitute the typology of wheat farmers who adopted the CA technology. It revealed that the majority had adopted all three components and it could be inferred that those who have accepted one component would probably also adopt the other components in time. While almost half the farmers sampled have adopted all three components of CA, 29.4% adopted only minimum tillage. Looking at soil cover, 49% of the farmers sampled, leave crop residue on the land and 76% indicated their crop rotation system whereas 23% did not indicate this. Those that did indicate the crops they used, mentioned wheat lucerne, rye and canola.

As mentioned, reasons behind participation in the CA farming system included increased total wheat yield and yield quality and improved weed management. More than 28% of the respondents simply argued that it was the 'best' farming practice. In general, farmers preferred the CA approach because it provides a means of conserving, improving and making more efficient use of their natural resources.

There is no blueprint for practicing conservation agriculture, as agro-ecosystems differ. A particularly important gap is the dearth of information on locally adapted cover crops that produce high amounts of biomass under prevailing conditions[4]. Trial and error, both by official institutes and the farmers themselves, is often the single source of information on how to select crops and schedule crop rotation.

7.4 Description of impacts

The assessments of impacts, including perceived financial, environmental, socio-economic and institutional impacts are summarized in table 2, which displays the perceived extent that CA has on crop production, the inputs required and the elements involved. This assists in exploring all the facets of CA that impact on soil quality, climate, pest, disease, labor, as well as access to mechanization, seeds, infrastructure, markets, and the economic status and culture of the practicing population.

The socio economic impact of the CA on wheat farmers was described in terms of its contribution to employment, income distribution and other indirect impacts. A relationship between CA adoption and income was perceived (table 2); farmers felt that adopting the CA approach would increase wealth as it enabled improved efficient production of grains and pastures, eventually facilitating economic growth.

Table 2 provides the appraisal by 51 respondents who assessed whether specific criteria had increased, remained constant or decreased. The majority of the respondents reported that total income per hectare had increased; non-agricultural income remained constant and specialized planning equipment prices have increased. This is in line with findings of other authors (Du Toit *et. al.* 2010) who concluded that high mechanization costs could be countered by assisting farmers to convert their existing implements. This process was evident in the study area, with the ARC in particular, assisting farmers in finding ways to develop cost effective equipment. Farmers further perceived that labour requirement and labour costs have decreased; weed control cost increased and credit cost remained constant.

[4] http//agriculture.indiabizclub.com

Table 2: Western Cape wheat farmers' perception of the Impacts of Conservation Agriculture (CA)

Impact	Increased/ improved		Decreased		Constant		Chi-square value	Probability value	Comments regarding the responses of 51 farmers
	#	**%**	**#**	**%**	**#**	**%**			**Majority of the farmers reported:**
CA Impact on total production	41	83.67	1	2.04	7	14.29	56.98	<0.01	Increased total production
Total income per ha	44	93.62	1	2.13	2	4.26	76.89	<0.01	Increased total income per hectare
Total income	41	87.23	1	2.13	5	10.64	61.95	<0.01	Increased total income
Non-agricultural income	10	33.33	1	3.33	19	63.33	16.20	0.0003	Constant non-agricultural income
Labour costs	3	6.52	32	69.57	11	23.91	29.60	<0.01	Decreased labour costs
planting equipment price:	37	82.22	7	15.56	1	2.22	49.60	<0.01	Increased specialized planning equipment prices
equipment costs	24	63.16	4	10.53	10	26.32	16.63	0.0002	Increased equipment costs
Weed control	26	59.09	12	27.27	6	13.64	14.36	0.0008	Increased weed control
Credit cost	6	15.38	16	41.03	17	43.59	5.69	0.058	Constant credit cost
Total labour needed	5	11.36	24	54.55	15	34.09	12.32	0.002	Decreased labour required
Hired labour	12	27.27	16	36.36	16	36.36	0.73	0.695	Tie: decreased and constant hired labour
Soil quality	46	95.83	1	2.08	1	2.08	84.38	<0.01	Increased soil quality
Soil moisture	44	93.62	1	2.13	2	4.26	76.89	<0.01	Increased soil moisture
Soil micro organism	46	95.83	1	2.08	1	2.08	84.38	<0.01	Increased soil micro organism
Temperature	5	11.63	21	48.84	17	39.53	9.67	0.008	Decreased temperature
Compaction	6	12.5	37	77.08	6	12.05	41.38	<0.01	Decreased compaction level
Human health:	21	58.33	5	13.89	10	27.78	11.17	0.001	Increased human health
Fertiliser cost	3	6.67	32	71.11	10	22.22	30.53	<0.01	
Pest control cost	20	43.48	13	28.26	13	28.26	2.13	0.345	Increased pest control
Insect/pest attack:	16	43.24	13	35.14	8	21.62	2.65	0.266	Increased insect attack
Production disease costs	3	6.52	37	80.43	6	13.04	46.22	<0.01	Decreased production disease costs
Crop disease:	10	27.78	19	52.78	7	19.44	6.50	0.039	Decreased crop disease
Water quality	26	65	1	2.5	13	32.5	23.45	<0.01	Improved water quality

Number of respondents

A full assessment of environmental impact requires complex analysis of physical, biological, social and economic processes (Anandajasekeram, *et. al.,* 2004), often beyond the scope of analyzing agricultural research activities. In this study, identifiable human concerns regarding environmental changes and environmental effects were considered. An increase in productivity was found, and this was directly related to soil health, as represented in table 2. Increased production and productivity correlates with increase in soil health, characterized by increased soil moisture, decreased temperature, increased micro-organism and decreased compaction. Although not measured, it can be assumed that the CA practices in the Western Cape increases organic matter and carbon levels, which improves soil structure; enhances water percolation and retention capacities; and captures $C0_2$-reducing GHG levels in the atmosphere (Horowitz, *et.al* 2012).

In terms of institutional impact, the Western Cape Department of Agriculture use wheat farmer study groups, constituting an institutionalized, group-based learning process where farmers use experiential learning in understanding the CA approach. These groups look at how CA technology is applied in terms of management of minimum or no-till land preparation and planting, and retention of crop residues following harvesting (Western Cape PDA, 2012). Activities also involve experiments, regular field observations and group analysis. The knowledge gained enables participants to make their own locally specific decisions on crop management practices. This approach represents a departure from earlier agricultural extension programmes, in which farmers are expected to adopt generalized recommendations that had been formulated by specialists from outside the community. Since farmers were introduced to the CA farming system by the combined ARC and Provincial Department of Agriculture efforts, capacity-building through study groups has proven successful, as the majority (81%) of farmers found the technology easy to adopt. It is envisaged that the CA system has been fully adopted, as 86% of farmers belong to study groups that deal with using and adopting the approach. Issues dealt with at these groups typically deal with different crop rotation options or minimum tillage issues. As mentioned, the most farmers reported that they learnt about the CA concept from the combined ARC/Provincial Department efforts and from other farmers.

The FAO (2007) states that institutional support tends to reduce the risk faced by farmers in adopting CA and thereby reduce their need for detailed information prior to adoption. This was confirmed by the active engagement of the Western Cape farmers. The Department's officials also indicated that the training offered contributed meaningfully to the farmers' adoption of Ca principles. This is confirmed by the fact that 81% of farmers stating that CA adoption was increasing, and a clear indication that farmers participating in the Department's study group sessions understand the principles of CA (Strauss, 2013).

8. QUANTITATIVE ANALYSIS AND RESULTS

One of the study objectives was to determine the farmer's economic return in adopting CA, using Benefit Cost Analysis. For this purpose quantitative experimental and GrainSA data was analysed. To complemented the data sourced through the survey, which only allowed for limited statistical analyses.

Two scenarios were used to quantify the impact of adopting conservation agriculture in wheat production in the Western Cape. The conventional wheat farming data, obtained as part of the experimental and GrainSA data set, provided counterfactual scenario, allowing for a comparison of CA adopters and those that still use conventional methods. This provided an estimation of the effects of the technology. This approach is almost similar to the one taken by Epplin *et. al.* (2005): It considered operations in continuous wheat monoculture for conventional and minimum-till (no-till) production systems. It also determined relative yield differences between no-till and conventional tillage. This data is also specific for the Western Cape, addressing the issue raised by Vink *et al* (1998) that it is important to account for differences in total variable costs per hectare between wheat production areas in South Africa. Hence the information in tables 3 and 4 is specific to wheat farmers in the Western Cape.

Table 3: Comparison of wheat production systems in the Western Cape in 2009/10 (GrainSA, 2014)

Price, yields and costs data	Conventional	CA
Price for best grade (R/ton) (Safex min marketing cost)	2639	2639
Yields (t/ha)	3	3
Gross prodn. Value (R/ha)	7577	7577
Direct Allocated Variable costs (R/ha)		
Seed	214.2	226.4
Fertiliser	926.56	773.5
Lime	27.5	27.5
Fuel	291.26	253.55
Reparation	288.01	303.66
Herbicide	1664.84	36.1
Pest control	91.35	29.9
Input insurance	211.38	211.38
Grain price entrenchment	189.61	
Contract Harvesting		287.91
Harvest insurance		101.83
Interest on production R/ha	251.56	135.1
Total Direct Allocated Variable Cost (R/ha)	4444.19	2386.84
Total overhead cost R/ha	841.59	841.59
Total cost per ha before marketing cost R/ha	5285.78	3228.43
Margin per ha before physical marketing and profit R/ha	2290.72	4348.07

Table 3 indicates that in the 2009/10 production season, to produce a yield of 3 tons per hectare through conventional and CA production methods cost R4 444/ha and R2 387/ha, respectively. Hence it was R2 057 cheaper to produce wheat with CA per hectare than with the conventional methods. IT also was 16.5% more expensive to fertilize a hectare in the conventional farming system than with the CA system, whilst a hectare in the conventional system required 46 times more herbicide.

Table 4: Comparison of wheat production systems in the Western Cape in 2013/14 (GrainSA, 2014):

Wheat production: Price, yields and costs	Conventional:	CA:
price for best grade (R/ton) (Safex min marketing cost)	2,922.00	2,917.00
Yields (t/ha)	3.3	3.5
Gross prodn. Value (R/ha)	8,751.60	9,264.50
Direct Allocated Variable costs (R/ha)		
Seed	401.25	351.09
Fertiliser	1740.00	1740.00
Lime	75.00	75.00
Fuel	736.30	459.31
Reparation	496.58	407.23
Herbicide	319.75	308.50
Pest control	220.15	220.15
Input insurance	257.46	272.59
Hedging	420.55	388.76
Harvest insurance	568.85	602.19
Crop dusting	100.00	100.00
Interest on production R/ha	373.51	344.74
Total Direct Allocated Variable Cost (R/ha)	5709.40	5269.57
Total Operational cost R/ha	2006.47	1186.89
Total cost per ha before marketing cost R/ha	7715.87	6456.45
Margin per ha before physical marketing and profit R/ha	1035.73	2808.05
Total cost before physical marketing R/ton	2338.14	1844.70
Total Marketing cost (R/ton)	478.00	483.00
Expected minimum Safex price without profit	2816.14	2327.70

Table 4 reveals that during the previous (2013/14) production season, the wheat yield under the CA system delivered an average yield of 3.5 t/ha, compared to 3.3t/ha under the conventional system. Both indicated a small yield increase compared to the 2009/10 season, probably due to improved practices and climatic conditions. Notably, the fuel cost when using conventional wheat production, was R277/ha more than with the CA system.

Table 5: Comparison of costs and benefits for with and without CA technology scenarios (2009/10)

With CA	**Costs(R/ha)**		**Income (R/ha))**	
	Total Direct Allocated Variable Cost (R/ha)	R2 386.84	Yield (ton/ha)*Wheat price (R/ton)3ton/ha*R2639/ton	R7917/ha
			Net income =R5 530.16	B/C ratio= total benefits /total direct costs =3.3
Without CA	Total Direct Allocated Variable Cost (R/ha)	R4444.19	Yield (ton/ha)*Wheat price (R/ton) 3ton/ha*R2639/ton	R7917/ha
			Net income = R3 472.81	B/Ct ratio=total benefits /total direct costs =1.8

Table 5 and 6 provide a comparison of summarised costs and benefits for the two seasons under evaluation. The general economic rule states that an intervention is considered financially viable when the Benefit/Cost (B/C) ratio is one and above.

For the 2009/10 production year, the 'with' CA scenario resulted in a B/C ratio of 3.3 while the 'without' CA scenario yielded a ratio of 1.8. In 2013/14 this was 1.8 'with' and 1.5 'without' CA. Hence, in both production seasons, it was more viable to produce wheat using the CA approach, than with conventional wheat production.

Table 6: Comparison of costs and benefits for with and without CA technology scenarios (2013/14)

With CA	**Costs(R/ha)**		**Income (R/ha))**	
	Total Direct Allocated Variable Cost (R/ha)	R5269.57	Yield(ton/ha)*Wheat price (R/ton) 3.5ton/ha*R2,917.00/ton	R9264.50/ha
			Net income = R3994.93/ha	B/C ratio=total benefits /total direct costs =1.8
Without CA	Total Direct Allocated Variable Cost (R/ha)	R5709.40	Yield (ton/ha)*Wheat price (R/ton) 3.3t/ha*R2,922.00/ha	R8751.60/ha
			Net income = R3 042.20	B/C ratio=total benefits /total direct costs =1.5

8.1 Analysing rotation of Langgewens experimental farm in the Western Cape

Apart from considering minimum till on wheat monoculture (treatment: wwww= wheat monoculture) the study also investigated crop rotation scenarios. Crop rotation data of the schedules practiced at the experimental farm at Langgewens were used to calculate gross margins for different crop sequences over the years. Wheat was the main crop rotated with clover, lupin, medic plant and canola. A Western Cape Department of Agriculture's interim report on the experimental data used gross margin analysis for each treatment plot for each year from 2002 to 2010. Table 7 illustrated variable costs, yield and gross margin for wheat monoculture over the years. There was no yield in the year 2003 even though there were costs incurred, that was due to severe drought in the province.

Table 7: Gross Margins for monocultured wheat at Langgewens experimental farm

Year	**Total Income**	**Total costs**	**Gross Margin**
2002	3591	2079	1511
2003	0	1863	-1863
2004	1703	1894	-191
2005	3656	1695	1961
2006	4856	1829	2979
2007	3906	2848	1058
2008	4911	1860	3050
2009	4844	3901	943
2010	5438	3533	1905

Gross income was calculated as yield per hectare multiplied by the product price at the date when delivered to the silo (during harvest). Quality was taken into account. Price per ton after silo and marketing costs was determined. The directly allocatable variable cost was determined as the actual price paid for products and services at the date the product or service was supplied to the trial site. Indirectly allocatable variable costs included energy cost was based on the average (coastal) price per litre (diesel) for the period April to October as supplied by the Automobile Association for a specific year. Fuel-use was based on 'Guide to Machinery costs' for a specific year for the actual machinery and implements used, as was repairs and maintenance.

Gross margins for crops in rotation are described in table 8, which clearly indicates the severe drought of 2003 and 2004 that affected the province. These results have been adapted from the Langgewens interim report compiled by the Western Cape Department of Agriculture (2002-2010). The gross margins realised differ among rotation systems both within and between years. This was, in part, due to large variations in allocatable variable costs, commodity prices and yields. The inherent variability in the production potential of soils across the study site also contributed to variability in the data set although the experimental design accounted for much of that variation.

Table 8: Gross Margin (R/ha) per crop per year in the 4th year of each crop sequence:

Crop Sequence	Crop in 4th year of sequence	Gross margin per crop in each crop sequence								
		2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
WWWW	**Wheat**	1511	-1863	-191	1961	2979	1058	3050	943	1905
CWWW	**Wheat**	1556	-2169	-831	3035	3335	6058	2248	1743	2490
WCWW	**Wheat**	1858	-1961	-162	2493	3778	5624	2910	1585	2546
WWCW	**Wheat**	3341	-1716	15	2362	4336	7191	4117	2527	3936
LCWW	**Wheat**	1503	-1674	-150	2832	3691	6336	5165	2376	4129
WLCW	**Wheat**	3280	-1846	-201	2494	5214	8465	8072	2930	5176
LWCW	**Wheat**	3619	-1708	559	3032	4606	6926	6824	2572	4531
CWLW	**Wheat**	3872	-1701	-112	2677	5462	8270	7157	3312	5761
MCMW	**Wheat**	4456	440	687	3021	5508	8883	7939	3575	5480
MWMW	**Wheat**	4749	317	510	2471	5849	7898	7159	3077	5231
McWMcW-1	**Wheat**	3874	214	489	2287	5591	7725	6217	2769	3983
McWMcW-2	**Wheat**	4914	439	468	2253	5640	8083	8603	3815	5952
WWWC	**Canola**	2688	-1548	-1408	524	1510	231	0	-2346	-940
WLWC	**Canola**	2882	-1550	-782	1332	1094	2354	3043	-688	-1740
WWLC	**Canola**	2941	-1622	-601	1158	630	1166	3934	-1873	-1035
MWMC	**Canola**	3536	-977	-1091	1579	1860	3317	7444	204	3747
CWWL	**Lupin**	-40	-1409	-99	63	236	1079	-818	-1503	127
WCWL	**Lupin**	124	-1516	-182	411	6	875	659	-985	324
WMWM	**Medic**	525	261	282	200	1096	1194	518	1095	1483
WMCW	**Medic**	603	371	-49	549	821	1570	1151	1353	2236
CMWM	**Medic**	603	373	406	611	1004	1570	1287	1322	2153
WMcWMc-1	**Medic/Clover**	452	134	28	309	1022	1579	790	905	1906
WMcWMc-2	**Medic/Clover**	794	521	382	578	1137	2003	1027	1723	2555

Key: 1-wheat monoculture (WWWW), 2-WWWC, 3-WCWL, 4-WWLC, 5-WMWM, 6-WMCM, 7-WMcWMc-1 and 8-WMcWMc-2 (where W = wheat, C = canola, L = lupin, M = medic & Mc = medic /clover mixed pasture).

In almost all years the lowest gross margins were recorded for the monoculture wheat system while the highest gross margins were recorded for the pasture-based wheat systems. One of the most important results from the analyses was that, whilst the gross margins achieved for canola and lupins were often negative, the inclusion of one or both of these crops into the production system resulted in improved gross margins ($P<0.05$) when compared to wheat monoculture. It also tended to increase ($P>0.05$) gross margins of the farming system as the proportion of wheat in the farming system was decreased. These findings support the hypothesis that crop rotation is viable.

8.2 Calculation of the effect of research on adoption of CA technology in wheat production

With the aim to estimate the effect of research in the field of CA technology as it pertains to wheat production, the study compared CA wheat yields at Langgewens experimental farm and conventional yields in the province.

Table 9: Variable costs (R/ha) for CA trials at Langgewens experimental farm and for farmers practicing CA (Experimental and GrainSA data) in the district:

Variables (R/ha)	Average costs (R/ha) of CA wheat production on Langgewens	Average costs (R/ha) of local wheat producers using CA in 2009/2010
Fertilizer	1868	773.6
Weed control	385	36.10
Pest control	35	29.90
Fungicides	195	
Fuel	165	253.55
Lime	150	27.50
Seed	464	226.40
Contract	305	
Repairs and maintenance	151	303.66
Grain price entrenchment		101.83
Input Insurance		211.38
Harvest Insurance		287.91
Interest on production		135.10
Total costs	**3565.5**	**2386.84**

Table 9 shows typical expenses incurred at the experimental farm and those incurred by farmers practising CA in the province. When comparing the 2009/2010 production season, the total costs of the CA trials were higher than those of farmers. This is the usual tendency with research trials being more expensive than typical farm production systems. The averaged costs were R3 565/ha and R2 386.84/ha respectively. It was also noted that fertilizer worth R1 868 was used per hectare on the trials whilst R774/ha was used by farmers; probably in response to a measured deficit at the experimental site.

Table 10 further explores differences between conventional and CA production systems in the Western Cape. Data from the Langgewens experimental farm, 28km from Malmesbury, and data from the Malmesbury area is used. Yield and quality is normally affected by variations in climate and soils, the incidence of pests and disease, and the management practices used to overcome natural constraints to production (Pardey *et.al* 2004). Since it matters where crops are grown as well as how much is grown in total, this table considered CA wheat yields at Langgewens experimental farm and conventional yields in the Malmesbury area. The total wheat yield per hectare in the Western Cape is also provided for production seasons under review.

Table 10: Comparative wheat yield per hectare for an experimental CA system and a conventional farming system (provincial Department data, DAFF data)

Farming system	**Areas**	**Ave. Wheat yield (t/ha)**				
		2005/06	06/07	07/08	08/09	09/10
With CA Technology	Langgewens	4.84	3.91	4.91	4.84	5.44
Without CA Technology	Malmesbury	2.86	3.05	3.11	3.15	2.67
Average Western Cape wheat yield (t/ha)		2.50	2.50	2.46	2.38	2.00

In table 11, average yields achieved, and markets prices sourced from the experimental farm at Langgewens and the Abstract of Agricultural statistics is used. Alston *et al*, (1998) stated that calculating the effects of research in agricultural production include estimating the effect of agricultural R&D on output, cost, profit and input use with a particular emphasis on developing measures of the benefit streams flowing from past investments in research. Although it is important to distinguish the growth consequence of the new technologies, using the before research benefits would be grossly overestimating the benefits of the technology. The correct way to show the growth results was to compute the without-R&D value of production which was given by quantity multiplied by price. An estimate of the value of R&D was deducted from the value of production with CA. After profits for both situations were calculated, the differences in profits were also computed.

Table11: Actual (with CA) and counterfactual (without CA) prices, yield and profits per ha, for Malmesbury farmers, compared to the Langgewens experimental farm:

Years	**Actual (CA) prices**	**Actual yields**	**without CA prices**	**Without CA yields**	**Profit (actual)**	**Profit (withoutl)**	**Difference (with-without**
	R/ha	t/ha	R/ha	t/ha	R/t	R/t	R/t
05/06	1446.0	4.84	1033.9	2.86	6998.6	2957.0	4041.7
06/07	2226.1	3.91	1524.2	3.05	8704.2	4648.8	4055.4
07/08	1811.7	4.91	2205.6	3.11	8895.4	6859.4	2036.0
08/09	1672.5	4.84	2307.5	3.15	8094.9	7268.6	826.3
09/10	2310.0	5.44	1607.7	2.67	12566.4	4292.6	8273.8

The difference in profit presented an estimation of profit obtained using the CA technology. The positive difference indicated that the intervention was beneficial. For example, in the 2005/06 production year the CA intervention yielded R4 041 more per hectare than where wheat was produced, in the same area, under conventional production.

Attribution of investment benefits

The ARC's involvement in promoting CA was working with the experimental farms but also with wheat producers using CA in the Western Cape generally. Assistance in terms of agronomic practices; technical advice on general production practices such as seeding densities, row width and fertiliser placement under CA conditions, was provided. The research costs of the ARC in 2005/2006 was R457 352.89, and an inflation adjusted figure of R577 397.49 was established as the ARC's research investment in 2009/2010, based on the assumption that ARC involvement was similar to that in 2005/2006.

Using the cost benefit data for the whole of the Western Cape, described in table 5, it is shown that the costs with CA technology were R2 386.84/ha in 2009/10, whilst the benefit achieved amounted to R7 917/ha, for a net benefit of R5 530.16/ha. The same table has shown that the costs without CA were R4 444.19 with a benefit of R7 917/ha, and a resultant net benefit of R3 472.81. The difference between R5 530.16/ha and R3 472.81 is R2 057.35. This difference presented an estimation of profit obtained using the CA technology. If this net benefit is multiplied by the acreage planted to wheat under CA in the Western Cape in 2009/10, which is calculated as roughly 166 000ha, the impact of the CA technology in that year was roughly 341.5 million.

Although this is a rough estimate, it is unlikely to be far from the reality on the ground. In the light of this, the ARC's investment of roughly R580 000 in the same year, can certainly be seen as a high value investment with huge returns.

The question is how much of the realised profit could be attributed to investment in agricultural research. Alston and Pardey (2001) agreed that it was difficult to attribute the contribution of research. Andajayasekaram and Babu (2007) suggested a number of strategies that could be used to address attribution through performance measurement, since there are other factors at play that could have affected the outcome in question (e.g. yield increase after a certain intervention). They also recommended that the cause-effect relationships in the programme's theory be unpacked. As part of the process one has to also use discriminating indicators. They emphasized that performance should be tracked over time and additional relevant evidence be gathered from, e.g. expert opinion or case studies.

Whilst it is acknowledged that ARC is just one of the stakeholders promoting CA through its research activities, even if the contribution attributed to the ARC is not specified, it clearly is highly significant.

8.3 Summary of quantitative results

When the production costs of 2009/10 production season were compared, it was found that to produce a yield of 3 tons per hectare through conventional and CA systems cost R4 444/ha and R2 387/ha in terms of direct costs, respectively. Overall it was R2 057 cheaper to produce wheat per hectare with CA. It also cost 16.5% more to fertilize a hectare in the conventional farming system than in the conservation system. A hectare in a conventional system also required 46 times the amount of herbicide applied to a hectare in the CA system. In both the 2009/10 and 2013/14 production years the B/C ratios were higher than 1 which was an indication that wheat production was financially viable but more efficient with CA technology.

Lastly the economic analysis looked at the contribution of CA systems to the profit made by farmers. Apart from the cost benefit data calculated for the Western Cape, the particular situation in the Malmesbury area was also determined. The increase in profit using the CA technology is highly significant, indicating that the intervention is viable.

The ARC's contribution in promoting CA in the Western Cape was determined, but the specific attribution of the ARC's role in profit was not attempted. Despite this attribution problem it could still be shown that the ARC's investment delivered a high return.

8. CONCLUSIVE RECOMMENDATIONS

The impact conservation agricultural practices in the /western Cape was determined in this study, using a survey and the analysis of quantitative data obtained from the Department of Agriculture in the Province, and from GrainSA.

It was concluded that the uptake of CA technology was significant in the province, and that apart from increasing profit margins, it also improves soil health, build soil structure, break up pest cycles, reduce soil erosion and improve water quality. It also found that the technology was not limited to specific field sizes or farmer profiles, confirming the versatility of the technology.

Since agro-ecosystems are different, farmers rely heavily on trial and error efforts and institutional effort such as study groups to integrate CA into their enterprises. Local organizations and farmers themselves develop their own information systems, critical for the adoption of the system

The study considered costs of operations in conventional and CA systems, as well as yields and profits. It was found that it is simply significantly cheaper to produce wheat with CA than with conventional methodology. Benefit/cost ratios are much higher for wheat production using CA technology than without CA technology. Also when the gross margins of different rotational systems practised at the Langgewens experimental farm were compared with conventional systems used in the adjacent district, it was found that profits were much higher using CA.

Apart from unequivocally recommending CA as the more sustainable and profitable system for wheat production in the Western Cape, collaborative efforts in implementing the CA system are also recommended.

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ANNEXURE A

English Questionnaire: **<u>CONSERVATION AGRICULTURE QUESTIONNAIRE</u>**

1. Age of the farmer/farm manager.

21-30 years	
31-40 years	
41-50 years	
51-60 years	
61-70 years	
71+ years	

2. What is the highest education level of the farmer/farm manager?

Formal schooling	
Diploma	
Degree	

3. How many years have you been farming when you started with conservation agriculture?

Number of years	

4. Which component of the CA package have you adopted?

Minimum soil disturbance(use of specialized equipment)	
Maximum soil cover/maximum stubble retention	
Diversified crop rotation	

5. What do you do with crop straws after harvesting?

Retain residue to protect the soil	
Bale for fodder	
Allow sheep to feed on them	
Remove part of straw	

6. Indicate how many hectares are currently (consider last planting season) under CA as opposed to conventional grain farming systems?

CA hectares	
Conventional hectares	

7. Indicate your crop rotation (CR) schedule since CA was introduced on the farm.
(Consider the latest 5 years pls)

Planting season	Crops	Yield/ha

8. Would you give the wheat yield data since the year you adopted the CA technology? (Consider the latest 5 years not more)

Year	Input cost/ha	Yield/ha

9. What are the benefits of crop rotation in relation to wheat farming

Increased amount of wheat yield	
Improved quality of wheat grain	
Weed management	
Other, specify	

10. How did you obtain the reduced tillage equipment?

Converted old equipment	
Hired equipment	
Bought new implement	
Combination of the above	

11. How do you find the application of CA in practice?

easy	difficult	undecided

Please provide a reason for your answer.

____
____

12. What are the major constraints to adoption of CA and possible solutions for your specific situation?

Constraints	**Solutions**

13. State the main driving forces for adoption? Tick appropriate answer. Is it:

13.1 Purely economic reason	
13.2 Best farming practice	
13.3 Easy to manage	
13.4 Reduce risk/diversify	
13.5 Other reasons, specify	

14. Do you think there is an increase in CA adoption in the region and nationwide?

Yes	No

15. How often do you seek assistance in applying any aspect of CA practice from the extension officers/Dept. officials/researchers?

Never	
Once a week	
Once a month	
Twice a month	
Other, specify	

16. When seeking assistance what are your queries mostly about?

Minimum soil disturbance(use of specialized equipment	
Maximum soil cover/maximum stubble retention	
Diversified crop rotation	
Other, specify	

17. Are you a member of farmer association or study group?

Yes	No

18. How was CA communicated to you?

Extension officers/Dept. officials	
ARC researchers	
Own research efforts	
Farmers	
Other, specify	

19. How did the adoption of CA affect aggregated crop production on your farm?

Increased	decreased	constant

20. How did the adoption of CA affect costs?

Labour wages	increased	decreased	constant
Output price	increased	decreased	constant
Fertiliser demand	increased	decreased	constant
Pesticides demand	increased	decreased	constant
Herbicides demand	increased	decreased	constant
Agricultural credit	increased	decreased	constant
Equipment cost	increased	decreased	constant

21. How did the adoption of CA affect income?

Crop Income (return/ha)	increased	decreased	constant
Agriculture income	increased	decreased	constant
Non-Agricultural income	increased	decreased	constant

22. How did the adoption of CA affect employment?

Hired labour demand	Increased	decreased	constant
Total labour demand	Increased	decreased	constant

23. How did the adoption of CA affect soil condition in general

Soil fertility	Increased	decreased	constant
Soil life(micro-organisms)	Increased	decreased	constant
Soil moisture	Increased	decreased	constant
Soil compaction	Increased	decreased	constant
Soil temperature	Increased	decreased	constant

24. How did the adoption of CA affect certain environmental components?

Human health: hazards	Increased	decreased	constant
Insect/pest attack	increased	decreased	constant
Crop disease	increased	decreased	constant
Water quality	deteriorated	improved	constant

Afrikaans Questionnaire

BEWARINGSLANDBOU VRAELYS VIR BOERE

1. Ouderdom van die boer/plaasbestuurder.

21-30 jaar	
31-40 jaar	
41-50 jaar	
51-60 jaar	
61-70 jaar	
71+ jaar	

2. Wat is die hoogste opleiding wat u as boer/plaasbestuurder ontvang het?

Formele skool opvoeding	
Landbou/Besigheids Diploma	
Landbou/Besigheids Graad	

3. Hoeveel jaar het u geboer voordat u met bewaringslandbou begin het?

Aantal jare	

4. Watter komponent van die Bewaringslandbou pakket het u aangeneem?

Minimum grondversteuring(gebruik gespesialiseerde toerusting)	
Maksimum grond bedeking	
Oes rotasie	

5. Wat doen u met die strooi (oesreste) na oestyd?

Behou oesreste om die grond te beskerm	
Baal dit vir voer	
Laat dit bewei	
Brand dit	

6. Dui aan hoeveel hektaar tans onder oesrotasie/bewaringslandbou is teenoor oppervlak onder konvensionele metodes

Hektaar onder bewaringslandbou	
Hektaar onder konvensionele praktyke	

7. Dui asseblief die oesrotasie skedule aan wat u gebruik in u bewaringslandbou stelsel

Plantseisoen (jaar)	Gewasse	Opbreng/hektaar

8. Kan u koringopbrengsdata gee vandat u bewaringslandbou toepas? (mees onlangse 5 jaar asb)

Jaar	Insetkoste /ha	Opbreng/ha

9. Wat is die voordele van bewaringslandbou in vergelyking met konvensionele koringboerdery?

Verhoogde totale koring opbreng	
Verbeterinde kwaliteit van koring graan	
Beter onkruid behandeling	
Ander (spesifiseer asseblief)	

10. Hoe het u die aangepaste toerusting nodig vir bewaringslandbou bekom?

Gehuurde toerusting	
Nuwe toerusting gekoop	
Kombinasie van bogenoemde	

11. Hoe ondervind u die toepassing van bewaringslandbou?

Maklik	Moelik	onseker

Gee asseblief 'n rede vir u antwoord.

____
____
____

12. Wat is na u mening die vernaamste potensiale beperkings van bewaringslandbou en wat is die moontlike oplossings?

Beperkings	**Oplossings**

13. Wat is die belangrikste redes waarom u bewaringslandbou toepas. Is dit:

Suiwer ekonomiese redes	
Beste volhoubare boerderypraktyk	
Maklik om te doen	
Verminder risiko	
Ander rede, spesifiseer	

14. Kan u sê of bewaringslandbou groei in die streek of nie?

Groei	Groei nie

15. Hoe gereeld vra u advies rakende bewaringslandbou van die Voorligter/Dept. beamptes/navorsers?

Een keer per week	
Een keer per maand	
Twee keer per maand	
Ander, spesifiseer	

16. Waaroor gaan u navrae meestal?

Minimum grondversteuring(gebruik van gespesialiseerde toerusting)	
Maksimum grondbedeking	
Verskillende oesrotasie opsies	
Ander, spesifiseer	

17. Is u lid van 'n studiegroep of boerevereniging?

Ja	Nee

18. Hoe het u te wete gekom van die bewaringslandbou konsep?

Voorligtingsbeamptes/Dept. beamptes	
LNR navorsers	
Eie navorsingspogings	
Boere	
Ander, spesifiseer	

19. Wat is die impak van bewaringsboerdery op u totale produksie?

Verhoging	Verlaging	konstant

20. Wat is die impak van bewaringsboerdery op koste?

Arbeidskoste	verhoging	verlaging	konstant
Gespesialliseerde toerustingskoste	verhoging	verlaging	konstant
Produksiekoste	verhoging	verlaging	konstant
Bemestingskoste	verhoging	verlaging	konstant
Pesbestrydingskoste	verhoging	verlaging	konstant
Onkruiddoderkoste	verhoging	verlaging	konstant
Kredietkoste	verhoging	verlaging	konstant
Toerusting prys	verhoging	verlaging	konstant

21. Wat is die impak van bewaringsboerdery op inkomste?

Inkomste/ha)	verhoging	verlaging	konstant
Totale inkomste	verhoging	verlaging	konstant
Nie-Landbou inkomste	verhoging	verlaging	konstant

22. Wat is die impak van bewaringsboerdery op indiensneming?

Gehuurde arbeid	verhoging	verlaging	konstant
Totale arbeid aanvraag	verhoging	verlaging	konstant

23. Wat is die impak van bewaringsboerdery op grondtoestand?

Grondvrugbaarheid	verhoging	verlaging	konstant
Grondlewe (mikro-organismes)	verhoging	verlaging	konstant
Grondvog	verhoging	verlaging	konstant
Grondtemperatuur	verhoging	verlaging	konstant
Grondkompaksie	verhoging	verlaging	konstant

24. Wat is die impak van bewaringsboerdery op geselekteerde omgewingsfaktore?

Menslike gesondheid	verhoging	verlaging	konstant
Insek plae	verhoging	verlaging	konstant
Oessiektes	verhoging	verlaging	konstant
Watergehalte	bedorwe	verbeterde	konstant

ANNEXURE B

SAS output

```
Western Cape Wheat farmers.SAS                  1
                                                         11:35
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Obs	IDNO	Farmpractice	Hector
1	Q1	CA	2000
2	Q1	Conventional	0
3	Q2	CA	1850
4	Q2	Conventional	.
5	Q3	CA	400
6	Q3	Conventional	.
7	Q4	CA	500
8	Q4	Conventional	.
9	Q5	CA	400
10	Q5	Conventional	.
11	Q6	CA	1500
12	Q6	Conventional	.
13	Q7	CA	1000
14	Q7	Conventional	400
15	Q8	CA	400
16	Q8	Conventional	0
17	Q9	CA	2400
18	Q9	Conventional	.
19	Q10	CA	900
20	Q10	Conventional	0
21	Q11	CA	950
22	Q11	Conventional	0
23	Q12	CA	1300
24	Q12	Conventional	0
25	Q13	CA	2000
26	Q13	Conventional	500
27	Q14	CA	250
28	Q14	Conventional	.
29	Q15	CA	600
30	Q15	Conventional	0
31	Q16	CA	600
32	Q16	Conventional	0
33	Q17	CA	250
34	Q17	Conventional	.
35	Q18	CA	400
36	Q18	Conventional	.
37	Q19	CA	240
38	Q19	Conventional	.
39	Q20	CA	600

40	Q20	Conventional	0
41	Q21	CA	600
42	Q21	Conventional	0
43	Q22	CA	2000
44	Q22	Conventional	.
45	Q23	CA	600
46	Q23	Conventional	0
47	Q24	CA	500
48	Q24	Conventional	.
49	Q25	CA	3000
50	Q25	Conventional	0
51	Q26	CA	600
52	Q26	Conventional	0
53	Q27	CA	1400
54	Q27	Conventional	0
55	Q28	CA	1350
56	Q28	Conventional	.
57	Q29	CA	200
58	Q29	Conventional	100
59	Q30	CA	2000
60	Q30	Conventional	.
61	Q31	CA	600
62	Q31	Conventional	0
63	Q32	CA	2500
64	Q32	Conventional	.
65	Q33	CA	1000
66	Q33	Conventional	100
67	Q34	CA	600
68	Q34	Conventional	0
69	Q35	CA	800
70	Q35	Conventional	200
71	Q36	CA	2000
72	Q36	Conventional	0
73	Q37	CA	600
74	Q37	Conventional	0
75	Q38	CA	300
76	Q38	Conventional	100
77	Q39	CA	600
78	Q39	Conventional	0
79	Q40	CA	334
80	Q40	Conventional	334
81	Q41	CA	600
82	Q41	Conventional	.
83	Q42	CA	1431
84	Q42	Conventional	.
85	Q43	CA	2800
86	Q43	Conventional	0
87	Q44	CA	1600
88	Q44	Conventional	1600
89	Q45	CA	1600
90	Q45	Conventional	0
91	Q46	CA	600

92	Q46	Conventional	0
93	Q47	CA	400
94	Q47	Conventional	0
95	Q48	CA	300
96	Q48	Conventional	.
97	Q49	CA	5000
98	Q49	Conventional	.
99	Q50	CA	500
100	Q50	Conventional	0
101	Q51	CA	600
102	Q51	Conventional	.

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The GLM Procedure

Class Level Information

Class	Levels	Values
Farm practice	2	CA Conventional

Number of Observations Read 102
Number of Observations Used 82

Salome Modiselle: Western Cape wheat farmers.SAS
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The GLM Procedure

Dependent Variable: Hector

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Farmpractice	1	18583752.28	18583752.28	32.65	<.0001
Error	80	45535582.66	569194.78		
Corrected Total	81	64119334.94			

R-Square	Coeff Var	Root MSE	Hector Mean
0.289831	105.0534	754.4500	718.1585

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The GLM Procedure

Level of Farmpractice	N	Hector Mean	Hector Std Dev
CA	51	1089.31373	924.581992
Conventional	31	107.54839	305.122362

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The GLM Procedure

t Tests (LSD) for Hector

NOTE: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Error Degrees of Freedom	80
Error Mean Square	569194.8
Critical Value of t	1.99006
Least Significant Difference	341.93
Harmonic Mean of Cell Sizes	38.56098

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

t Grouping	Mean	N	Farmpractice
A	1089.3	51	CA
B	107.5	31	Conventional

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The UNIVARIATE Procedure

Variable: rHector

Moments

N	82	Sum Weights	82
Mean	0.0181523	Sum Observations	1.48848868
Std Deviation	1.0917134	Variance	1.19183816
Skewness	2.96417666	Kurtosis	13.9610634
Uncorrected SS	96.5659102	Corrected SS	96.5388907
Coeff Variation	6014.18741	Std Error Mean	0.12055958

Basic Statistical Measures

Location		Variability	
Mean	0.01815	Std Deviation	1.09171
Median	-0.14402	Variance	1.19184
Mode	-0.14402	Range	7.60970
		Interquartile Range	0.95605

Tests for Location: Mu0=0

Test	-Statistic-		-----p Value------	
Student's t	t	0.150567	Pr > |t|	0.8807
Sign	M	-18	Pr >= |M|	<.0001
Signed Rank	S	-385.5	Pr >= |S|	0.0736

Tests for Normality

Test	--Statistic---		-----p Value------	
Shapiro-Wilk	W	0.742194	Pr < W	<0.0001
Kolmogorov-Smirnov	D	0.23285	Pr > D	<0.0100
Cramer-von Mises	W-Sq	0.915238	Pr > W-Sq	<0.0050
Anderson-Darling	A-Sq	4.889925	Pr > A-Sq	<0.0050

```
                    Quantiles (Definition 5)

                    Quantile       Estimate

                    100% Max       6.416053
                    99%            6.416053
                    95%            1.919865
                    90%            1.222866
                    75% Q3         0.303380
                    50% Median    -0.144019
                    25% Q1        -0.652670
                    10%           -0.921889
                    5%            -1.057401
                    1%            -1.193643
                    0% Min        -1.193643


                     Extreme Observations

          ------Lowest-----        -----Highest-----

             Value      Obs           Value      Obs

          -1.19364       57         1.91987       63
          -1.13905       37         2.05079       88
          -1.12542       33         2.35413       85
          -1.12542       27         2.65249       49
          -1.05740       95         6.41605       97


                         Missing Values

                                -----Percent Of-----
          Missing                             Missing
            Value       Count     All Obs         Obs

                .          20       19.61      100.00

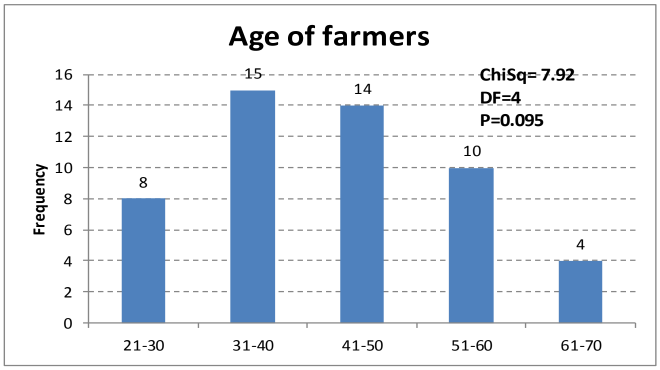

            Stem Leaf                          #
Boxplot
               6 4                             1
*
               5
               5
               4
               4
               3
               3
               2 7                             1
0
```

```
                 2 14                                     2
0
                 1 89                                     2
0
                 1 022222                                 6
|
                 0 55577                                  5
|
                 0 133344                                 6             +-
-+--+
                -0 4321111111111111111111111111000       31             *-
----*
                -0 999998887777777777777             21             +-
----+
                -1 2111110                                7
|
                   ----+----+----+----+----+----+-

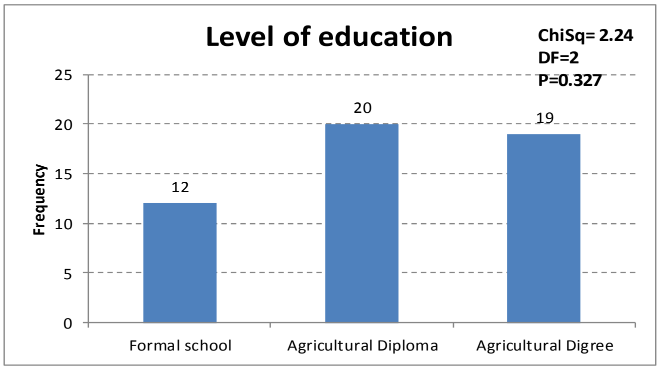
                                  Normal Probability Plot
                 6.25+
*
                     |
                     |
                 4.75+
                     |
                     |
                 3.25+
                     |                                                 *
+++
                     |                                           *  *+++
                 1.75+                                        +**++
                     |                                   ++****
                     |                               ++++**
                 0.25+                          +++++ ***
                     |                      ***********
                     |             **********
                -1.25+ *   *  *  ****++++
                      +----+----+----+----+----+----+----+----+----+---
-+
                          -2        -1         0        +1        +2
```

ANNEXURE C

Age	Frequency	Percent
21-30	8	15.69
31-40	15	29.41
41-50	14	27.45
51-60	10	19.61
61-70	4	7.84



Heducation	Frequency	Percent
Formal school	12	23.53
Agricultural Diploma	20	39.22
Agricultural Digree	19	37.25



PracticalExp	Frequency	Percent
0	6	12.5
1	3	6.25
2	7	14.58
3	4	8.33
4	1	2.08
5	3	6.25
6	2	4.17
7	1	2.08
8	1	2.08
10	6	12.5
12	2	4.17
13	1	2.08
15	2	4.17
20	3	6.25
21	1	2.08
25	1	2.08
28	1	2.08
30	3	6.25