CONSERVATION AGRICULTURE IN SOUTH AFRICA

1. Introduction:

Attaining food security at household, national, regional and global levels requires a shift to more efficient and sustainable food production practices. Conservation Agriculture (CA) is increasingly being recognised as one of the more sustainable ways of farming in Southern Africa and can be adapted for different farming levels and circumstances.

CA is an application of modern agricultural technologies to improve production, while at the same time protecting and enhancing the land resources on which production depends. Application of CA promotes the concept of optimizing yields and profits while ensuring provision of local and global environmental benefits and services.

In deference to other approaches, CA promotes a series of principles to achieve conservation objectives, rather than a particular technology. CA is based on the principles of rebuilding the soil, optimizing crop production inputs (including labour) and optimizing profits.

CA can be defined as per a statement given by the Food and Agricultural Organisation of the United Nations as, "a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment" (FAO, 2007).

CA is the umbrella term commonly given to conservation tillage, no-tillage, direct-drilling, minimum-tillage and/or ridge-tillage, and "deklaagbewerking".

2. Key principles:

The Food and Agricultural Organisation of the United Nations (FAO) has determined that CA has three key principles that producers (farmers) can follow in order to apply the process of CA.

1. Minimum Soil Disturbance: Minimum soil disturbance refers to low disturbance of the crop growing area. The disturbed area must be less than 15 cm wide or less than 25% of the crop area (whichever is lower). There should be no periodic tillage that disturbs a greater area than the aforementioned limits. Strip tillage is allowed if the disturbed area is less than the set limits.

The first key principle in CA is to practice minimum mechanical soil disturbance which is essential to maintaining minerals within the soil, stop erosion and prevent water loss from occurring in the soil. In the past agriculture has looked at soil tillage as the main process in the introduction of new crops to an area. It was believed that tilling the soil would increase fertility within the soil through mineralization that takes place in the soil. Today tillage is seen as a way of destroying organic matter that can be provided within the soil. CA farming has become a process that can save soil organic levels for a longer period of time, and still allow the soil to be productive for longer periods. (FAO, 2007).

2. Organic soil cover: The surface of the soil is permanently covered by live or dead vegetation. (This should preferably be apart from the planting line or hole).

The second key principle in CA is about managing the top soil to create a permanent organic soil cover and allow growth of organisms within the soil structure. This growth will break down the mulch that is left on the soil surface. The breaking down of this mulch will produce a high organic matter level which will act as a fertilizer for the soil surface. If the practices of CA are being done for many years and enough organic matter is being built up at the surface, then a layer of mulch would start to form. The layer of mulch that is built up over time will start to become like a buffer zone between soil and mulch that will help reduce wind and water erosion. Also, with this, comes the protection of the soil surface with rainfall. Rainfall on land that is not protected by a layer of mulch is left open to the elements and it has a direct impact on the soil. This type of ground cover would also help to keep the temperature lower and the moisture level of the soil will increase compared to using the till method.

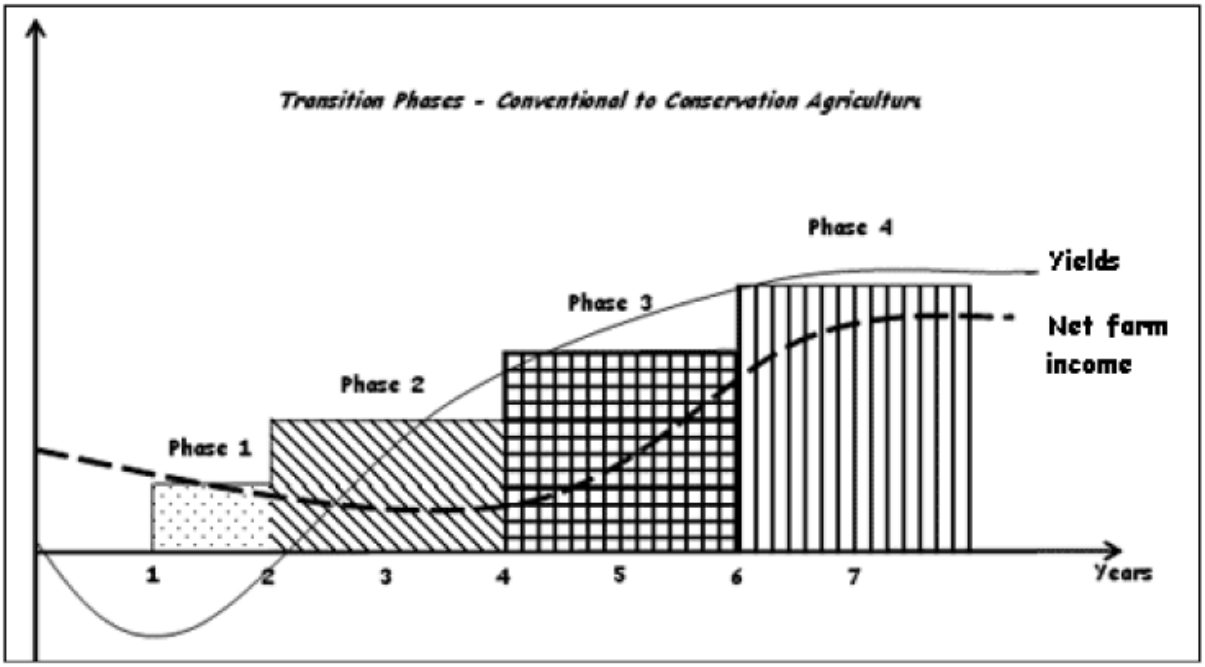
3. Crop rotation: A variety of crops are grown in rotation, or sequence, or together with the main crop.

The third and final principle is the practice of crop rotation with more than two crop species. Rotational crops will act as a natural insecticide and herbicide for specific crops. To prevent insects or weeds establishing a pattern in fields will help to eliminate problems with yield reduction and infestations (FAO, 2007). Establishing crops in a rotation allows for an extensive build up of rooting zones which will allow for better water penetration.

3. Benefits of Conservation Agriculture:

The benefits will be looked at in relation to minimal soil disturbance, permanent ground cover and rotation, since they all interact to provide the benefits, which include the following:

1. Yields and farm income: It is important to recognize the effect that CA has on two of the main aims of crop production – the optimization of yields and net farm income. Drawn from experiences across the globe, the Food and Agriculture Organisation (2007) has drafted a theoretical representation to show how these variables are affected in the first few years after adopting CA (See figure below).



The figure furthermore shows the general trend in net farm income after CA is adopted. In the first two phases, a marginal decrease in net farm income can be expected. Thereafter, an exponential increase in the third phase can be expected and a levelling off in the fourth phase in the early stages of adoption can be largely attributed to two processes. The first process is that of familiarization and adaptation on the part of the farmer. Mistakes and inefficiencies occur inevitably in the early days, but, as time goes by, the farmer becomes more familiar with the techniques, improves on practices and management and learns from previous mistakes. The second process is where the biophysical environment's natural balance is restored (Food and Agriculture Organisation, 2007). As the soil is not tilled as much anymore, several soil conditions (fertility, porosity and soil moisture content for example) are improved and this normally results in greater yields. It must, however, be noted that the figure only gives a general idea of what is normally expected to happen with regard to yields and net farm income. (Du Toit, 2007).

A research project done by du Toit, 2007, indicated that No-Tillage (NT) farmers in the North West Province reported yield increases of 13% in the first year, which is slightly less than the Reduced Tillage farmers with 16%. However, from the third year onwards, a significant increase in NT yields compared to that of Reduced Tillage was observed. Although deep rip tillage (RT) accounts for higher yields in the

first few years after adoption, NT yields tend to exceed that of Reduced Tillage in the long-run. For example, at the end of the first five years, NT yields were 34% higher compared to conventional cultivation. This increase in yield can primarily be attributed to improved soil conditions, which increases soil fertility and soil moisture content (Du Toit, 2007).

2. Time management: One of the major benefits of CA, which makes it popular with farmers, is that it is economical and saves time. Since planting can be accomplished in one pass of the seed drill, the planting time is reduced. Planting time after the first rainfall is normally hectic and conventional system farmers have to wait for the first summer rains before they can plant, while the CA farmers can plan their planting time, because there is ample moisture conserved for planting before the first rains and the upper soil does not dry out quickly, which enables CA farmers to plan the planting process more accurately.

3. Water-use efficiency: Systems using CA show reduced water run-off, better water penetration and more moisture in the soil throughout the growing period. The total rainfall for South Africa is relatively lower than other crop production areas globally and the effect of better water usage will encourage farmers to adopt the CA principles. Farmers expressed CA to be of immeasurable help in their quest to utilise the country's limited rainfall as efficiently as possible. One could then understand why Mallett (1981) remarks that, "any technique that can be economically introduced to make better use of our limited and often unreliable moisture supplies must therefore be encouraged." (Reported by Du Toit, 2007).

4. Increased microbial activity leads to better soil quality: The surface mulch helps promote more stable soil aggregates as a result of increased microbial activity and better protection of the soil surface. Ground-cover promotes an increase in biological diversity below and above ground; there are more beneficial organisms and these help keep insects in biological balance. Furthermore, the biological diversity and activities will create a network of interconnected pores, nutrient recycle and the soil's physical and biological health. Life in the soil is a highly complex and dynamic system that is sensitive to tillage, pesticides, and other toxins.

5. Nutrition efficiency: During the first 2-3 years after adopting CA, nitrogen fertilizer efficiency may be lower as a result of micro-organisms tying up the nitrogen in the residue (Nitrogen negative periods). However, in other longer-term experiments, release of nutrients increased with time because of more active microbial activity and nutrient recycling.

6. Less fuel and lower carbon emissions: CA systems are using less diesel fuel and thus results in lower carbon dioxide emissions, one of the gases responsible for global warming. In combination with the reduction of mechanization requirements, this is very cost effective.

7. Less weeds: Weeds have been shown to germinate less in CA systems because the soil is less disturbed than in tilled soils. There is also evidence of allelopathic properties of cereal residues in respect of inhibiting surface weed seed germination. Weeds will also be controlled when the cover crop is cut, rolled flat, or killed by herbicides. Farming practices that maintain soil micro-organisms and microbial activity can also lead to weed suppression by biological agents. Proper weed control is one of the main barriers why producers hesitate to change to a full CA system, however, after successfully applying the chemicals; weed control is not an issue anymore.

8. Social benefits: Besides the economic and biological benefits, there are also various other reasons why they adopt conservation practices. These can include non-individual or societal interests (Food and Agriculture Organization, 2001), the pride that comes from being a steward of the environment, a strong concern for the environment and/or even because they feel it is "the right thing to do". Adopting CA is a challenge with a reward.

9. Environmental climatic changes: One last argument to strengthen the case of CA adoption is the threat of possible detrimental impact which future climatic changes may hold. The Centre for Environmental Economics and Policy in Africa (CEEPA) has carried out extensive research on the impact of projected climate change in Africa. In their study on South Africa, they indicate maize production in the areas near Lichtenburg (in the North West province) to become economically unfeasible by the year 2060 because of significant reductions in rainfall. They recommend that, "given the fact that currently up to 57% of this district is cultivated, of which the majority (90%) is under maize, there is a definite warning sign that some form of alternative has to be sought if maize production is to be maintained at current levels" (Benhin, as reported by Du Toit, 2007).

Drivers of adoption

The main reason why participants adopt CA has been to improve and restore the overall condition of the soil. To reduce soil erosion and the degradation of lands have been other important reasons why farmers adopted CA. To reduce expenses on fuel and mechanization was also another important consideration. It would, therefore, seem that the improvement and restoration of their most important natural resource – the soil – and the reduction of farm input costs, are the most important factors for the adoption of CA.

What will it take to change?

More and more farmers are interested in practising CA and just need extra encouragement to be convinced. Some farmers, however, are waiting for fellow farmers to pave the way and sort out the problems before they will join. The agricultural situation in South Africa is ready to promote CA and

farmers are hungry to adopt such a system. The aspect in need of change is the traditional way in which producers, scientists and researchers think about crop production. International CA experts visiting South Africa, state that, "South Africa has a huge potential to rapidly increase the area under conservation agriculture, if the main obstacle, mindset, is overcome."

What is required is the urgent and immediate adoption of technologies being refined and exploited in other countries. Not just because it will improve biological health, but it also reduces global warming and environmental pollution, increases the life span of dams, reduces the cost of water purification etc., but primarily because it makes good economic sense for farmers, i.e. the persons most immediately and directly affected.

Because of the conservative and risk aversion nature of farmers the suggestion to focus initial conservation agriculture work in finer textured sandy soils and in areas with higher rainfall makes sense and should result in more success and faster adoption.

It is important to use a bottom-up, farmer participatory approach to promote this technology. Seeing and doing is believing and farmers must be able to experiment with the technology in their own situations in order to fully understand how it can help them produce more at less cost and with benefits to the natural resource base and environment.

Barriers to adoption

Farmers identified the following three issues as the main barriers in adopting CA: soil compaction, lack of information, and hidden risks and uncertainties. The first barrier is the sandy nature of soil in the Central and Western areas which needs tilling to avoid soil compaction and crusting. Research projects on South African soils show that soils which have less than 20% clay in the upper layer are very vulnerable to compaction. However, in Western Australia, an area with similar climatic and production conditions as South Africa, a significant adoption of no-tillage has taken place despite the area's infertile sandy soils, with clay contents typically between 1% and 5% (Crabtree, 2000). The trend is that CA is easier adopted in the tropical and subtropical eastern areas of South Africa and less to the central and western areas in the direction of the marginal production conditions (in the direction of the Kalahari desert).

External experts summarized the following Constraints (Fowler, 2005).

1. mindset - farmers soon adopt a technique that can be seen to work.
2. machinery - now available, both local and imported.
3. risk aversion of farmers - CA reduces risk by retaining rainfall.

4. availability of technology - this already exists in the internationally CA adopted countries.
5. dependence on herbicides - diminishes fast with proper weed management and glyphosate resistant crops.
6. difficulty of controlling weeds without herbicides - delayed erratic germination due to mulch, allelopathy of cover crops, prevention of seeding and reduced mechanical disturbance soon negate this.
7. lack of economic data – a database will make on-farm cost comparisons available.
8. inaccessibility of information - fast diminishing as technology improves, e.g. search for CA on websites.
9. inappropriate technology – this is reduced as the needs of farmers are defined and extension materials are field tested.
10. retention of mulches - changing in plant populations and row width, animal feeding and subsidised fences, etc.
11. Cover crop – one of the most crucial problems to address.

Most importantly, more and more farmers and advisers are eager to see the system working, for it is this that will attract the farmers the most. To give momentum to this evolvement, demonstration plots that demonstrate successful practices are of interest and these should be established by farmers, not extension workers. CA adoption in South Africa is becoming more and more popular due to soil quality, economic, management, labour, and mechanical benefits. The adoption for CA systems by summer grain producers in Mpumalanga and KwaZulu-Natal, is close to 50 percent of farmers and gradually less for the Free State and the North Western dryer, sandy areas of South Africa (less than 5 percent). It is estimated that reduced forms of tillage are practiced on approximately 34.6% (1,522,718ha) of South Africa's total cultivatable area (4,402,255ha) and that 8.6% (377,169ha) is under no-tillage. In the North West province, in particular, reduced forms of tillage are practised on approximately 32.4% (392,289ha) of the province's arable lands and no-tillage on 5.2% (62,960ha) (Du Toit, 2007).

The practice of mouldboard ploughing reduced substantially over the past years, however, the majority of farmers are still disturbing the soils with ripping, tilling and disking operations. Although the plough has great ability in preparing a suitable seedbed and controls weeds effectively, its appropriateness in very dry regions in South Africa has been questioned by many scholars: "In a province such as the North West, which has low precipitation water, conservation is of the utmost importance. By inverting soils by 135º, the plough dries out what little moisture is housed in the topsoil, thereby wasting the most precious and critical commodity needed in crop production. Furthermore, ploughing destroys the soil's natural structure and promotes the loss of organic matter and soil organisms, leaving the soil bare and unprotected from the destructive forces of rain, wind and heat" (Du Toit, 2007).

Non-inversion tillage systems, such as no-tillage (NT), reduced tillage (RT), and minimum tillage (MT) and "Deklaagbewerking" are regarded as sustainable methods for preparing a soil bed for crop production. In combination with CA principles, farmers normally follow a strict traffic control system where the wheels of tractors and equipment are limited to predetermined tracks. CA fanatic followers do not allow unnecessary traffic on fields, such as dumpcarts, during harvesting. Of great assistance during operations is precision technology.

The crop production conditions in South Africa differ from other successful CA producing countries and existing research results cannot be applied directly in many cases. The differences are mainly due to rain and soil conditions. South African farmers are successfully producing crops with rainfall as low as 400 mm per year on soil with a clay percentage of up to 50 percent and sometimes less than 5% in the sandy areas in the central and North Western regions. Furthermore, our winters are not as cold with no snow coverage. However, winter temperatures are close to zero and very dry, which limits successful growing of cover crops. The sandy soils are vulnerable to compaction and need to be ripped from time to time. For this reason the strip-till system is attractive. The covering of soil surfaces with plants or dead material is a challenge for moisture conservation practices in the fallow period for up to eighteen months. Crop rotation is limited in most areas to two crops, namely maize and soyabeans. Well adapted varieties of alternative crops need to be developed in future.

In many areas there is a very short seeding 'window' due to the low and uncertain rainfall at the beginning of the season. Partly as a result of the above, seeding machines should have the ability to operate accurately at relatively high speed in cloddy soils, and the intensive and apparently inevitable use of tines in direct seeding machines may result in high power demand, variation in seeding depth and clogging. Tines are the best and cheapest solutions to operate with soil obstacles, in contrast to the views of international experts who suggest discs. Well designed tines with correct angles and small width can be a solution to use in soils compacted during ploughing. The use of tines often results in greater furrow depth and consequently increases power requirements. This negative effect also appears when a tine is used in dry soil. Special precautions need to be taken where tines cause a potting effect and limit root development and space. In such cases, it will be better to use discs to put the kernels just under the surface of the soil and protect it with loose soil and organic material (Hennie Vermooten, personal communication).

The conventional agricultural systems of small scale farmers involve land preparation before rains and seeding. The result is that, in general, soil preparation is poor and this problem is increased with the use of contractors. Conventional animal traction seeders used in South Africa have limitations to operate with

clods over the soil surface and the seed metering devices employed are of poor quality. The farmer tradition of using own and therefore unsized maize seed enhances the poor performance of seed metering devices (Fowler, 2005). Experience, however, is that small scale farmers are subsidised by government and have access to the highest technology seeds for insect and herbicide resistance. Small scale farmers will benefit by training, demonstrations and mentoring by successful farmers.

The following main problems were identified for conservation agriculture mechanization: soil hardness, caused by tractor traffic or mouldboard plough use; soil obstacles, like gravel as a consequence of advanced soil erosion process; steep slopes; short seeding time due to low rainfall; low power capacity of the animals (oxen and donkeys); and loss of tradition of animal traction use. Soil compaction occurs annually in the central part of the Free State and needs to be broken up on a regular basis (Gerrie Jacobs, personal communication).

At present, as noted by international visitors, even some of the more sophisticated systems practised by, for example, commercial farmers of the KwaZulu-Natal No-Till Club, lack some of the components of the principles of Direct-seeded Mulch-based Cropping (DMC) systems, in that they rely heavily on chemicals, both fertilisers and pesticides (the latter being sprayed systematically rather than on thresholds), and that "true" rotations are seldom part of the systems (Fowler, 2005).

Finally, at all times the temptation to "reinvent the wheel" should be avoided, with technology and equipment already being available elsewhere, but should be thoroughly evaluated before being applied locally.

The critical aspect for the success of CA in South Africa is undoubtedly in the identification and utilisation of green manure cover crop (GMCC) species. In Brazil green manure cover crops, alone or in combination, are used to *inter alia* penetrate compacted layers in the soil; complex aluminium; fix nitrogen; 'pump up' water and/or nutrients from depth; stimulate or retard soil microbial populations; break disease cycles; balance nematode populations; induce germination or dormancy of weed species; attract or repel insects; etc. Here in South Africa characteristics such as these could be of real benefit to both small and large scale farmers, but the utilisation of GMCC will be dependent on adapted species (rye, oats, barley, beans, etc.) and the regular reliable production of seed.

On many commercial farms and in most communal areas crop residues provide out-of-season nutrition for livestock. CA requires that all or most of the crop residues be retained for surface cover, with the result that one of the major constraints to adoption of the CA system is being the provision of an alternative source of feed.

South Africa has a number of farmer 'typologies', which can be broadly divided into resource-poor and commercial farmers. The farms of the resource-poor farmers comprise a homestead garden and two or more fields totalling 1 to 5 hectares where they grow maize, partly or primarily for 'green mealies' and the rest for consumption or for sale. The constraints they face when attempting to adopt CA are primarily a lack of appropriate advice and money to purchase inputs and often an inability to preserve the mulch on their fields due to livestock. CA, however, has tremendous potential benefits, especially to the many female-headed households and those directly or indirectly affected by, for example, HIV/AIDS. Solutions include 'living fences', re-education of advisers, encouragement and assistance of 'master farmers', etc., but mentoring by commercial farmers may need special attention due to the vastly different circumstances of the two groups.

The commercial farmers, on the other hand, have much to gain from the reduced costs and greater flexibility of CA systems, but urgently need advice on especially the possibilities, including how to handle sandy soils, situations capable of producing minimal biomass for mulches, the need for and possible alternative rotation crops, and how to convert from conventional to conservation tillage systems.

Other agronomic information will have to be addressed in the near future regarding row width, plant populations, plant genotypes, fertilizer formulations and applications, use of herbicides and pesticides, and soil borne diseases. This new technology may bring about a totally new era in crop production in South Africa.

Training

Training of farmers and extension agents are needed in CA and kitchen garden activities. Development of simple, visual training materials and introduction of farmer field schools (or some other name) where farmers interact closely with trainers/facilitators should accelerate adoption. Trainers or facilitators could be selected from among bright young people in the villages who undergo practical training at the universities and get a diploma for their efforts. They return to their villages to act as catalysts and have the option of returning to the university for collecting information from experts to resolve farming problems, and for attending refresher courses. A way has to be determined for compensating these facilitators for their time in the villages.

Conclusion

There is a general lack of information and statistics concerning CA in South Africa. This information is also required by the FAO for an international data base and by the national CA task team, which is at present seeking to formulate South African policies.

Global warming is now a fact not a theory and fossil fuel is becoming increasingly scarce and expensive. The rivers are still running red with our topsoil and our agricultural potential is reducing at an ever-increasing rate.

The bottom-line is that the CA system offers a financially healthier crop production practice worldwide by reducing input costs and stabilising environmental conditions. World commodity prices are becoming increasingly competitive and the result of international trade agreements is that South African products have to compete locally as well as internationally with products from the rest of the world.

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