APPENDIX A

STRATEGY OF THE MAIZE FORUM AND MAIZE TRUST FOR CONSERVATION AGRICULTURE RESEARCH IN SOUTH AFRICA

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1. Background to conservation agriculture

"The condition of our soils ultimately determines human health by serving as a major medium for food and fibre production and a primary interface with the environment, influencing the quality of the air we breathe and water we drink. Thus, there is a clear linkage between soil quality and human and environmental health. As such, the health of our soil resources is a primary indicator of the sustainability of our land management practices." - Acton and Gregorich, 1995

Introduction:

Conservation agriculture (CA) aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations. CA holds tremendous potential for all sizes of farms and agro-ecological systems, but its adoption is perhaps most urgently required by smallholder farmers, especially those facing acute labour shortages. It is a way to combine profitable agricultural production with environmental concerns and sustainability and it has been proven to work in a variety of agro ecological zones and farming systems. It is been perceived by practitioners as a valid tool for Sustainable Land Management (SLM).
Internationally the FAO's view is that CA can only work optimally if the different technical areas are considered simultaneously in an integrated way.

What is Conservation Agriculture (CA)?

Conservation Agriculture (CA) is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment.

CA is characterized by three linked principles, namely:

- Continuous minimum mechanical soil disturbance.
- Permanent organic soil cover.
- Diversification of crop species grown in sequences and/or associations.

CA principles are universally applicable to all agricultural landscapes and land uses with locally adapted practices. CA enhances biodiversity and natural biological processes above and below the ground surface. Soil interventions such as mechanical tillage are reduced to an absolute minimum or avoided, and external inputs such as agrochemicals and plant nutrients of mineral or organic origin are applied optimally and in ways and quantities that do not interfere with, or disrupt, the biological processes.

CA facilitates good agronomy, such as timely operations, and improves overall land husbandry for rain fed and irrigated production. Complemented by other known good practices, including the use of quality seeds, and integrated pest, nutrient, weed and water management, etc., CA is a base for sustainable agricultural production intensification. It opens increased options for integration of production sectors, such as crop-livestock integration and the integration of trees and pastures into agricultural landscapes.

Conventional "arable" agriculture is normally based on soil tillage as the main operation. The most widely known tool for this operation is the plough, which has become a symbol of agriculture. Soil tillage has in the past been associated with increased fertility, which originated from the mineralization of soil nutrients as a consequence of soil tillage. This process leads in the long term to a reduction of soil organic matter. Soil organic matter not only provides nutrients for the crop, but it is also, above all else, a crucial element for the stabilization of soil structure. Therefore, most soils degrade under prolonged intensive arable agriculture. This structural degradation of the soils results in the formation of crusts and compaction and leads in the end to soil erosion. The process is dramatic under tropical climatic situations but can be noticed all over the world. Mechanization of soil tillage, allowing higher working depths and speeds and the use of certain implements like ploughs, disk harrows and rotary cultivators have particularly detrimental effects on soil structure.

Soil erosion resulting from soil tillage has forced us to look for alternatives and to reverse the process of soil degradation. The logical approach to this has been to reduce tillage. This led finally to movements promoting conservation tillage, and especially zero-tillage, particularly in southern Brazil, North America, New Zealand and Australia. Over the last two decades the technologies have been improved and adapted for nearly all farm sizes; soils; crop types; and climatic zones.

Experience has shown that these techniques, summarized as conservation agriculture (CA) methods, are much more than just reducing the mechanical tillage. In a soil that is not tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer protects the soil from the physical impact of rain and wind but it also stabilizes the soil moisture and temperature in the surface layers. Thus this zone becomes a habitat for a number of organisms, from larger insects down to soil borne fungi and bacteria. These organisms macerate the mulch, incorporate and mix it with the soil and decompose it so that it becomes humus and contributes to the physical stabilization of the soil structure. At the same time this soil organic matter provides a buffer function for water and nutrients. Larger components of the soil fauna, such as earthworms, provide a soil structuring effect producing very stable soil aggregates as well as uninterrupted macro pores leading from the soil surface straight to the subsoil and allowing fast water infiltration in case of heavy rainfall events.

This process carried out by the edaphon, the living component of a soil, can be called "biological tillage". However, biological tillage is not compatible with mechanical tillage and with increased mechanical tillage the biological soil structuring processes will disappear. Certain operations such as mouldboard or disc ploughing have a stronger impact on soil life than others as for example chisel ploughs. Most tillage operations are, however, targeted at loosening the soil which inevitably increases its oxygen content leading in turn to the mineralization of the soil organic matter. This inevitably leads to a reduction of soil organic matter which is the substrate for soil life.

Thus agriculture with reduced, or zero, mechanical tillage is only possible when soil organisms are taking over the task of tilling the soil. This, however, leads to other implications regarding the use of chemical farm inputs. Synthetic pesticides and mineral fertilizer have to be used in a way that does not harm soil life.

As the main objective of agriculture is the production of crops, changes in the pest and weed management become necessary with CA. Burning plant residues and ploughing the soil is mainly considered necessary for phytosanitary reasons: to control pests, diseases and weeds. In a system with reduced mechanical tillage based on mulch cover and biological tillage, alternatives have to be developed to control pests and weeds. Integrated Pest Management becomes mandatory. One important element to achieve this is crop rotation, interrupting the infection chain between subsequent crops and making full use of the physical and chemical interactions between different plant species. Synthetic chemical pesticides, particularly herbicides are, in the first years, inevitable but have to be used with great care to reduce the negative impacts on soil life. To the extent that a new balance between the organisms of the farm-ecosystem, pests and beneficial organisms, crops and weeds, becomes established and the farmer learns to manage the cropping system, the use of synthetic pesticides and mineral fertilizer tends to decline to a level below that of the original "conventional" farming system.

Why CA?

Conservation Agriculture, understood in this way, provides a number of advantages on global, regional, local and farm level:

- It provides a truly sustainable production system, not only conserving but also enhancing the natural resources and increasing the variety of soil biota, fauna and flora (including wild life) in agricultural production systems without sacrificing yields on high production levels. As CA depends on biological processes to work, it enhances the biodiversity in an agricultural production system on a micro- as well as macro level.

- No till fields act as a sink for CO_2 and conservation farming applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. Farmers applying this practice could eventually be rewarded with carbon credits.
- Soil tillage is among all farming operations the single most energy consuming and thus, in mechanized agriculture, air-polluting, operation. By not tilling the soil, farmers can save between 30 and 40% of time, labour and, in mechanized agriculture, fossil fuels as compared to conventional cropping.
- Soils under CA have very high water infiltration capacities reducing surface runoff and thus soil erosion significantly. This improves the quality of surface water reducing pollution from soil erosion, and enhances groundwater resources. In many areas it has been observed after some years of conservation farming that natural springs that had dried up many years ago, started to flow again. The potential effect of a massive adoption of conservation farming on global water balances is not yet fully recognized.
- Conservation agriculture is by no means a low output agriculture and allows yields comparable with modern intensive agriculture but in a sustainable way. Yields tend to increase over the years with yield variations decreasing.
- For the farmer, conservation farming is mostly attractive because it allows a reduction of the production costs, reduction of time and labour, particularly at times of peak demand such as land preparation and planting and in mechanized systems it reduces the costs of investment and maintenance of machinery in the long term.

Disadvantages in the short term might be the high initial costs of specialized planting equipment and the completely new dynamics of a conservation farming system, requiring high management skills and a learning process by the farmer. Decomposition of cover crops can lead to a deficit of nitrogen at the beginning of the growing period. Long term experience with conservation farming all over the world has shown that conservation farming does not present more or less but different problems to a farmer, all of them capable of being resolved.

The main principles of conservation agriculture

Conservation agriculture systems utilize soils for the production of crops with the aim of reducing excessive mixing of the soil and maintaining crop residues on the soil surface in order to minimize damage to the environment.

By doing this CA will:

Provide and maintain an optimum environment of the root-zone to maximum possible depth. Roots are able to function effectively and without restrictions to capture high amounts of plant nutrients and water.

- Ensure that water enters the soil so that (a) plants never, or for the shortest time possible, suffer water stress that will limit the expression of their potential growth; and so that (b) residual water passes down to groundwater and stream flow, not over the surface as runoff.
- Favour beneficial biological activity in the soil in order to (a) maintain and rebuild soil architecture; (b) compete with potential in-soil pathogens; (c) contribute to soil organic matter and various grades of humus; (d) contribute to capture, retention, chelating and slow release of plant nutrients.
- Avoid physical or chemical damage to roots that disrupts their effective functioning.

The three principles of conservation agriculture include:

- Direct planting of crop seeds
- Permanent soil cover, especially by crop residues and cover crops
- Crop diversity

The principles of CA and the activities to be supported are described as follows:

- *Maintaining permanent soil cover and promoting minimal mechanical disturbance of soil through zero tillage systems, to ensure sufficient living and/or residual biomass to enhance soil and water conservation and control soil erosion.*

In turn, this improves soil aggregation, soil biological activity and soil biodiversity, water quality, and increases soil carbon sequestration. Also, it enhances water infiltration, improves soil water use efficiency, and provides increased insurance against drought. Permanent soil cover is maintained during crop growth phases as well as during fallow periods, using cover crops and maintaining residues on the surface;

- *Promoting a healthy, living soil through crop rotations, cover crops, and the use of integrated pest management technologies.*

These practices reduce requirements for pesticides and herbicides, control off-site pollution, and enhance biodiversity. The objective is to complement natural soil biodiversity and to create a healthy soil microenvironment that is naturally aerated, better able to receive, hold and supply plant available water, provides enhanced nutrient cycling, and better able to decompose and mitigate pollutants. Crop rotations and associations can be in the form of crop sequences, relay cropping, and mixed crops.

- *Promoting application of fertilizers, pesticides, herbicides, and fungicides in balance with crop requirements.*

Feed the soil rather than fertilize the crop. This will reduce chemical pollution, improve water quality, and maintain the natural ecological integrity of the soil, while optimizing crop productivity and economic returns;

- *Promoting precision placement of inputs to reduce costs, optimize efficiency of operations, and prevent environmental damage.*

Treat problems at the field location where they occur, rather than blanket treatment of the field, as with conventional systems. Benefits are increased economic and field operation efficiencies, improved environmental protection, and reduced (optimized) input costs. Precision is exercised at many levels: seed, fertilizer and spray placement; permanent wheel placement to stop random compaction; individual weed killing with spot-spraying rather than field spraying, etc. Global positioning systems are sometimes used to enhance precision, but farmer sensibility in problem diagnosis and precise placement of treatments is the principal basis. In small-scale farming systems and horticultural systems, it also includes differential plantings on hills and ridges to optimize soil moisture and sunshine conditions;

- *Promoting legume fallows (including herbaceous and tree fallows where suitable), composting and the use of manures and other organic soil amendments.*

This improves soil structure and biodiversity, and reduces the need for inorganic fertilizers.

Direct seeding or planting:

Direct seeding involves growing crops without mechanical seedbed preparation and with minimal soil disturbance since the harvest of the previous crop. The term direct seeding is understood in CA systems as synonymous with no-till farming, zero tillage, no-tillage, direct drilling, etc. Planting refers to the precise placing of large seeds (maize and beans for example); whereas seeding usually refers to a continuous flow of seed as in the case of small cereals (wheat and barley for example). The equipment penetrates the soil cover, opens a seeding slot and places the seed into that slot. The size of the seed slot and the associated movement of soil are to be kept at the absolute minimum possible. Ideally the seed slot is completely covered by mulch again after seeding and no loose soil should be visible on the surface.

Land preparation for seeding or planting under no-tillage involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control, and seeding directly through the mulch. Crop residues are retained either completely or to a suitable amount to guarantee the complete soil cover, and fertilizer and amendments are either broadcast on the soil surface or applied during seeding.

Permanent soil cover

A permanent soil cover is important to protect the soil against the deleterious effects of exposure to rain and sun; to provide the micro and macro organisms in the soil with a constant supply of "food"; and alter the microclimate in the soil for optimal growth and development of soil organisms, including plant roots.

The effects of soil cover:

- Improved infiltration and retention of soil moisture resulting in less severe, less prolonged crop water stress and increased availability of plant nutrients.
- Source of food and habitat for diverse soil life: creation of channels for air and water, biological tillage and substrate for biological activity through the recycling of organic matter and plant nutrients.
- Increased humus formation.
- Reduction of impact of rain drops on soil surface resulting in reduced crusting and surface sealing.
- Consequential reduction of runoff and erosion.
- Soil regeneration is higher than soil degradation.
- Mitigation of temperature variations on and in the soil.
- Better conditions for the development of roots and seedling growth.

Means and practices:

- Use of appropriate/improved seeds for high yields as well as high residue production and good root development.
- Integrated management and reduced competition with livestock or other uses e.g. through increased forage and fodder crops in the rotation.
- Use of various cover crops, especially multi-purpose crops, like nitrogen-fixing, soil-porosity-restoring, pest repellent, etc.
- Optimization of crop rotations in spatial, timing and economic terms.

- " Targeted" use of herbicides for controlling cover crop and weed development.

Crop rotation

The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro organisms, but as they root at different soil depths, they are capable of exploring different soil layers for nutrients. Nutrients that have been leached to deeper layers and that are no longer available for the commercial crop, can be "recycled" by the crops in rotation. This way the rotation crops function as biological pumps. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna, as the roots excrete different organic substances that attract different types of bacteria and fungi, which in turn, play an important role in the transformation of these substances into plant available nutrients. Crop rotation also has an important phytosanitary function as it prevents the carryover of crop-specific pests and diseases from one crop to the next via crop residues.

The effects of crop rotation:

- Higher diversity in plant production and thus in human and livestock nutrition.
- Reduction and reduced risk of pest and weed infestations.
- Greater distribution of channels or bio pores created by diverse roots (various forms, sizes and depths).
- Better distribution of water and nutrients through the soil profile.
- Exploration for nutrients and water of diverse strata of the soil profile by roots of many different plant species resulting in a greater use of the available nutrients and water.
- Increased nitrogen fixation through certain plant-soil bio symbioses and improved balance of N/P/K from both organic and mineral sources.
- Increased humus formation.

Means and practices:

- Design and implementation of crop rotations according to the various objectives: food and fodder production (grain, leaf, stalks); residue production; pest and weed control; nutrient uptake and biological subsurface mixing / cultivation, etc.
- Use of appropriate / improved seeds for high yields as well as high residue production of above-ground and below-ground parts, given the soil and climate

Advantages and disadvantages of CA

To be widely adopted, all new technology needs to have benefits and advantages that attract a broad group of farmers who understand the differences between what they are doing and what they need. In the case of conservation agriculture these benefits can be grouped as:

- Economic benefits that improve production efficiency.
- Agronomic benefits that improve soil productivity.
- Environmental and social benefits that protect the soil and make agriculture more sustainable.

Economic benefits

Three major economic benefits can result from CA adoption:

- Time saving and thus reduction in labour requirement.
- Reduction of costs, e.g. fuel, machinery operating costs and maintenance, as well as a reduced labour cost.
- Higher efficiency in the sense of more and stabile output for a lower input.

The positive impact of conservation agriculture on the distribution of labour during the production cycle and, even more important, the reduction in labour requirement are the main reasons for farmers in Latin America to adopt conservation agriculture, especially for farmers who rely fully on family labour.

Agronomic benefits

Adopting conservation agriculture leads to improvement of soil productivity:

- Organic matter increase and Microbial community biodiversity
- In-soil water conservation.
- Improvement of soil structure, and thus rooting zone.

The constant addition of crop residues leads to an increase in the organic matter content of the soil. In the beginning this is limited to the top layer of the soil, but with time this will extend to deeper soil layers. Organic matter plays an important role in the soil: fertilizer use efficiency, water holding capacity, soil aggregation, rooting environment and nutrient retention, all depend on organic matter.

Baseline data for the impact of agricultural management practices (AMP) on soil microbial populations is limited for South African soils. As a result, an unsaturated demand to quantify the impact of various AMP on soil physicochemical and biological properties exists. This information is essential ensuring that accurate recommendations can be provided to farmers on AMP to sustain soil health and quality, in order to maximize profitability. While agricultural practices (e.g. tillage, cropping sequence, fertilization inputs, and irrigation) are known to have significant effects on the physical and chemical properties of soil, less is known about the associated effects on the biological
aspects of the soil. Microbial community biodiversity, on the other hand, is a facet that is often neglected, despite the integral part it plays in soil quality and maintenance of ecosystem functioning.

Environmental benefits:

- Reduction in soil erosion, and thus of road, dam and hydroelectric power plant maintenance costs.
- Improvement of water quality.
- Improvement of air quality.

- Biodiversity increase.
- Carbon sequestration.

Residues on the soil surface reduce the splash-effect of the raindrops, and once the energy of the raindrops has dissipated the drops proceed to the soil without any harmful effect. This results in higher infiltration and reduced runoff, leading to less erosion. The residues also form a physical barrier that reduces the speed of water and wind over the surface. Reduction of wind speed reduces evaporation of soil moisture.

Soil erosion is reduced close to the regeneration rate of the soil or even adding to the system due to the accumulation of organic matter. Soil erosion fills surface water reservoirs with sediment, reducing water storage capacity. Sediment in surface water increases wear and tear in hydroelectric installations and pumping devices, which result in higher maintenance costs and necessitates earlier replacement.

More water infiltrates into the soil with conservation agriculture rather than running off the soil surface. Streams are then fed more by subsurface flow than by surface runoff. Thus, surface water is cleaner and more closely resembles groundwater in conservation agriculture than in areas where intensive tillage and accompanying erosion and runoff predominate. Greater infiltration should reduce flooding, by causing more water storage in soil and slow release to streams. Infiltration also recharges groundwater, and thus increasing well supplies and revitalizing dried up springs.

Sediment and dissolved organic matter in surface water must be removed from drinking water supplies. Less sediment loss and less soil particles in suspension, lead to a reduced cost for water treatment.
One aspect of conventional agriculture is its ability to change the landscape. The destruction of the vegetative cover affects the plants, animals and micro-organisms. Some organisms profits from the change and may turn into pests. However, most organisms are negatively affected and either they disappear completely or their numbers are drastically reduced. With the conservation of soil cover in conservation

agriculture a habitat is created for a number of species that feed on pests, which in turn attracts more insects, birds and other animals. The rotation of crops and cover crops restrains the loss of genetic biodiversity, which is favoured with mono-cropping.

Systems, based on high crop residue addition and no tillage, accumulate more carbon in the soil, compared to the loss into the atmosphere resulting from plough-based tillage. During the first years of implementing conservation agriculture the organic matter content of the soil is increased through the decomposition of roots and the contribution of vegetative residues on the surface. This organic material is decomposed slowly, and much of it is incorporated into the soil profile, thus the liberation of carbon to the atmosphere also occurs slowly. In the total balance, carbon is sequestered in the soil, and turns the soil into a net sink of carbon. This could have profound consequences in the fight to reduce green house gas emissions into the atmosphere and thereby help to forestall the calamitous impacts of global warming.

Limitations of conservation agriculture

The most important limitation in all areas where conservation agriculture is practised is the initial lack of knowledge. There is no blueprint available for conservation agriculture, as all agro-ecosystems are different. A particularly important gap is the frequent dearth of information on locally adapted cover crops that produce high amounts of biomass under the prevailing conditions. The success or failure of conservation agriculture depends greatly on the flexibility and creativity of the practitioners and extension and research services of a region. Trial and error, both by official institutes and the farmers themselves, is often the only reliable source of information.

However, as conservation agriculture is gaining momentum rapidly in certain regions, there now exist networks of farmer organizations and groups of interested people who exchange information and experiences on cover crops, tools and equipment and other techniques used in conservation agriculture.

As conservation agriculture partly relies on the use of herbicides, at least during the initial stage of adoption, some people worry that adoption of conservation agriculture will increase herbicide use and that in turn will lead to increased contamination of water by herbicides. In fact experience has shown that herbicide use tends to decline over time as the soil cover practices prevent weed emergence.

Reductions in leaching of pesticides under conservation agriculture might be caused by greater microbial activity degrading pesticides faster or to greater organic matter adsorbing the pesticides.

The importance of cover crops in conservation agriculture

Keeping the soil covered is a fundamental principle of CA. Crop residues are left on the soil surface, but cover crops may be needed if the gap is too long between harvesting one crop and establishing the next.
Cover crops improve the stability of the CA system, not only on the improvement of soil properties but also for their capacity to promote an increased biodiversity in the agro-ecosystem.

While commercial crops have a market value, cover crops are mainly grown for their effect on soil fertility or as livestock fodder. In regions where smaller amounts of biomass are produced, such as semi-arid regions or areas of eroded and degraded soils, cover crops are beneficial as they:

- Protect the soil during fallow periods.
- Mobilize and recycle nutrients.
- Improve the soil structure and break compacted layers and hard pans.
- Permit a rotation in a monoculture.
- Can be used to control weeds and pests.

Cover crops are grown during fallow periods, between harvest and planting of commercial crops, utilizing the residual soil moisture. Their growth is interrupted either before the next crop is sown, or after sowing the next crop, but before competition between the two crops starts. Cover crops energize crop production, but they also

present some challenges.
Cover crops are useful for:

- Protecting the soil, when it does not have a crop.
- Providing an additional source of organic matter to improve soil structure.
- Recycling nutrients (especially P and K) and mobilizing them in the soil profile in order to make them more readily available to the following crops.
- Provide "biological tillage" of the soil; the roots of some crops, especially cruciferous crops, like oil radish are pivotal and able to penetrate compacted or very dense layers, increasing water percolation capacity of the soil.
- Utilizing easily leached nutrients (especially N).

Different plants, with diverse rooting systems, explore different soil depths within the profile. They may also have the ability to absorb different quantities of nutrients and produce distinct root exudates (organic acids) resulting in benefits both for the soil and for the organisms.

The presence of a mulch layer (of dead vegetation) in conservation agriculture inhibits the evaporation of soil moisture, yet leads to greater water infiltration into the soil profile. The percentage of rainwater that infiltrates the soil depends on the amount of soil cover provided.

Vegetative cover is important in CA for the protection of the soil against the impacts of raindrops; to keep the soil shaded; and maintain the highest possible moisture content. We have seen their importance for nutrient recycling; but they also have a physical and, perhaps, an allelopathic effect on weeds, depressing their incidence and leading to a reduction in agrochemical use and thus in production costs.

Straw residues function as a cushion that reduces the pressure on the soil under wheels and hooves and so they play an important role in reducing soil compaction.

The incorporation of cover crops will be a challenge for the central and western summer rainfall areas in South Africa. The main objective is to conserve ample moisture in the fall to fill the soil profile. Planting a cover crop on the fields will reduce the available plant moisture for the next crop. This will be an area for research.

Cover crop and residue management

Conservation agriculture systems start each year with the production and distribution of crop residues or an additional cover crop.

Erroneously, it is often thought that Conservation Agriculture can only be successfully implemented if herbicides are applied. Fortunately, the creativity and persistence of many farmers and researchers has led to the current situation in which a lot of knowledge and equipment exist to manage cover crops WITHOUT the use of herbicides.

Vegetative material adequately managed:

- Adds organic matter, which improves the quality of the seedbed and increases the water infiltration and retention capacity of the soil.
- Fixes carbon by capturing carbon dioxide from the atmosphere and retaining it in the soil.
- Buffers the pH of the soil and facilitates the availability of nutrients.
- Feeds the carbon cycle of the soil.
- Captures the rainfall and thus increases the soil moisture content.
- Protects the soil from being eroded.
- Reduces the evaporation of soil moisture.

Residues badly managed:

- Provoke an unequal drying of the soil and thus a delay in the warming-up of the seedbed or uneven germination of the crop.
- Interfere with sowing and fertilizing activities.

- Hinder the emergence of seedlings.

In conservation agriculture, residues should be manipulated from harvest onwards. It depends on the following cover crop whether or not the residues should be distributed equally over the field or left intact.

An equal distribution of residues provides homogenous temperature and humidity conditions. If residues are not distributed more or less equally on the soil surface, this may cause the following problems:

- Bad placement of the seeds at sowing, resulting in an uneven germination.
- A cold and wet seed environment favours the development of pests and diseases.
- Allelopathy may be encouraged.

It is important to choose the precise moment at which the vegetative cover is controlled, because most of the species used can regenerate if their growth is interrupted prematurely. Alternatively, seeds of the cover crop can germinate if the plants are allowed to mature, as may happen with oats, rye, chickpea, vetches and forage radish. There are, however, species and rotations where cover crops are purposely brought to maturity to establish a seed bank which will allow the cover crop to grow automatically once the cash crop is harvested.

The best moment to control the majority of cover crop species is at the full flowering stage when they have accumulated maximum biomass. In the case of legumes, the pods from the first flowering should be already formed but not yet mature. Oats and rye can be best managed at the milk stage. Horse radish can be slashed at any growth stage, but in systems of direct sowing and minimum tillage, seeds should be green and physiologically immature to avoid the germination of new plants. Both sunn-hemp and pigeon pea need to be controlled before flowering due to a high re-growth rate and excessive wood development in the stems.

The most adequate way to manage the cover crops depends on the objective of the cover crop and the possibilities of the farmer. If the requirement is for the dead mulch to

cover the soil for as long as possible, the best way to manage the biomass is by using a knife-roller, chain, sledge or herbicides.
When the decomposition process has to start immediately in order to release the nutrients it is recommendable to slash or mow the cover crop. In some cases it might be necessary to complete this with herbicides.
The period between slashing, or other management practice, of the cover crop and seeding of the commercial crop (maize, beans, soya, etc.) can affect the production level of the crop. This is related to some of the substances that are released during decomposition of the cover crops. These can harm the germination of the crop seeds, or sometimes even delay the development of subsequent crops. This is called allelopathy. In general, management of leguminous cover crops and horse radish ten days before planting of maize gives the highest yield responses.

The maize yield on cover of grass species, such as rye, oats and Italian ryegrass, increases with an increase in the number of days between managing the cover crop and seeding the maize. This is related to a reduction of nitrogen immobilization and allelopathic effects over time and different levels of lignin and hemicelluloses.

Economic aspects of Conservation Agriculture (1)
Unfortunately, short-term solutions and immediate benefits always attract farmers and the full technical and economic advantages of conservation agriculture can be seen only in the medium- long-term run, when its principles (no-tillage, permanent cover crop and crop rotation) are well established within the farming system.

In fact, if the two systems (conventional and conservation agriculture) are applied in two plots with the same agro-ecological and fertility conditions, no great differences in productivity during the first years are to be expected. However, after cultivating the same crops in the same areas for several years, the differences between the two systems become more evident.

CA requires a new way of thinking from all concerned. Along with this "new way of thinking agriculture", there is already enough technical and agronomic evidence that could positively influence farmers contemplating the adoption of CA principles. It is, however, important to demonstrate to farmers that the technical and agronomic aspects are directly related to the management and economic ones and, therefore, any technical and agronomic improvements obtained by applying CA principles need to be quantified in monetary and economic terms.

Before analysing the farm management and economic aspects of CA, it is illuminating to divide the adoption/adaptation process into four theoretical phases.

- First Phase - Improvement of tillage techniques: During this first phase, no increase in farm output is foreseen. But decreases in: labour; time; draught animal or motorised power (reduction of production costs) would occur. An increase in agro-chemical use, especially to control weeds might be required. Furthermore, there may be a reduction of production in comparison with the conventional agriculture;
- Second Phase - Improvement of soil conditions and fertility. Decreases in labour, time, animal and motorised power (reduction of production costs). Increases in yields and consequently increase in net farm income;
- Third Phase - Diversification of cropping pattern. Increased and more stable yields. Increased net farm income and soil fertility.
- Fourth Phase - The integrated farming system is functioning smoothly. Stability in production and productivity. The full technical and economic advantages of conservation agriculture can be appreciated by the farmer.

Technological changes

Because of the opportunities for increased outputs, reduction in production costs and higher income levels which a technological change to CA can offer; it is useful to take into consideration the process of adoption / adaptation and diffusion of technical innovations. The economic potential of conservation agriculture, in terms of costs of production, profit, yield, soil conservation, etc. is very important. However, unfamiliarity with conservation agriculture practices might make the initial impact on yield and input usage uncertain. It should not be forgotten that the adoption / adaptation decision must take place in an uncertain environment (subject to the vagaries of nature and the market). Farmers' attitudes to risk and, in particular, their strategies for risk aversion must also be taken into consideration.

There are four requirements for the adoption of CA practices:

- It must bring the farmer a visible and immediate benefit, economic or otherwise.
- The benefit must be substantial enough to convince the farmers to change their ongoing practices.
- For the technology to be disseminated, the costs incurred must be able to be covered by the farmer.
- The introduction of CA should be followed up by an extension service for a long period of time.

The potential conservation agriculture adopter / adapter may be confronted with constraints in terms of purchasing power; access to credit and information; and poor communications links with product and input markets. In this regard, the availability of inputs in the quantity and at the time required may prove to be important considerations in the adoption / adaptation process.

Managing changes in input use

In principle, the cost of some inputs (e.g. for seed purchase) should not differ in conservation agriculture compared to conventional tillage. However, differences are often observed and can be explained through:

- In conservation agriculture less seed is needed because the losses in the field are reduced. However, sometimes more seed is needed because the plant density in conservation agriculture is optimal and might be higher than under traditional dibble stick planting. So, in effect, seed use remains about the same. In conservation agriculture cover crops play an important role and if the seeds for cover crops are not produced on-farm, the farmer needs to buy them elsewhere.

- Fertilizer costs (Nitrogen) are initially considered to be more under conservation agriculture compared to conventional tillage. However, as the organic matter of the soil increases under conservation agriculture, so will the soil fertility and moisture content. Both aspects lead to an increased fertilizer efficiency, which will reduce fertilizer need in the long run.
- Farmers who are used to applying herbicides under conventional system will also use them under conservation agriculture. Experience shows that in these cases herbicide costs will reduce over time as the permanent soil cover exerts its weed-controlling function. Herbicides are important, but farmers using conventional tillage methods use similar amounts of herbicides as no-tillage farmers.
- Those farmers, who have never used herbicides because they are simply not available or very expensive, are likely to adopt alternative practices for weed control.
- When conservation agriculture is practised correctly, pest and disease incidence will be lower compared to conventional tillage due to crop rotation and the use of cover crops. Consequently, the cost for treatment will also be reduced. Experience in South Africa is that negative soil borne pathogens may also increase and have a negative effect on the crop especially in limited moisture conditions. This will be an area to research.
- The reduction in labour- and equipment requirements and cost is one of the main reasons for the adoption of CA.

Machinery and Equipment

In the majority of the farms where conservation agriculture is practised, fewer operations are executed in the field. For this reason farmers need less equipment and the costs of both labour (see above) and fuel are reduced. In addition, the number of implements can be reduced; ploughs and harrows are no longer required. In the case of tractor-powered farming, the size of the tractor can also be reduced: for ploughing a heavier tractor is needed compared to direct seeding and spraying.

Likewise, in animal draught systems, fewer animals are needed, or different types of animals can be used: instead of one pair of oxen, a pair of donkeys might be sufficient.

Fewer field operations result in less wear and tear of the equipment, which in turn will have a longer life span and the costs for maintenance and repair are reduced considerably.

Crop yields

In general, conservation agriculture can produce equivalent or higher yields compared to conventional tillage systems. Crop yields may fall in the initial phases of CA adoption, and will only raise above conventional tillage figures when the CA system has stabilised. Statistically reliable data need to be collected to prove yield levels in South Africa. Historically farmers believe to open the soil and turn it over as deep as possible and on the short term positive results are normally observed.

Carbon sequestration

CA does, of course, provide many environmental benefits that may not be of direct interest to the farmer. Here, for example, we are thinking about streams and rivers running free of eroded soil and so not silting up reservoirs or damaging hydro-electric generating turbines. Another major benefit is the reduction of damage done to roads and, indeed marine environments, by reducing runoff and erosion; to say nothing of the costs of domestic water purification.

However, CA is currently receiving global focus for its carbon sequestration potential. It has been calculated that the total potential for soil carbon sequestration by agriculture could offset about 40% of the estimated annual increase in CO2 emissions. CA practices that sequester soil organic matter contribute to environmental quality and the development of sustainable agricultural systems. The significance of CA adoption to the amelioration of effects of greenhouse gas emissions on global climate change is now being evaluated. The emergence of carbon credit payments for CA farmers is being considered seriously and could result in a further financial benefit to CA adopters.

2. Introduction to the Strategy

The Strategy for Conservation Agriculture Research of the Maize Forum (endorsed by the Maize Trust) comprises an inspiring Vision, Mission, Goals and Objectives. The practical application of research, adopting of the principles and mind change of farmers as well as the mutually beneficial collaboration and networking among researchers from government departments, the ARC and Institutes, universities, agricultural input companies in South Africa, are fundamental to the success of this strategy.

The Maize Forum envisages that the effective implementation of the Strategy would lead to the creation of a virtual Centre of Excellence for Conservation Agriculture Research in Maize (and other agricultural crops) in South Africa by 2014.

3. Elements of the strategy

3.1 Vision for Conservation Agriculture Research at the Maize Forum

Achieving sustainable and profitable agriculture and subsequently improve the livelihoods of maize farmers *in South Africa.*

3.2 Mission for Conservation Agriculture research at the Maize Forum

It is the mission of the Maize Forum to coordinate and provide resources for relevant research activities, facilitating practical applications and harness farmers with useful information as a practical tool to use in Conservation Agriculture.

3.3 Goal for Conservation Agriculture research at the Maize Forum

Conservation agriculture (CA) aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and crop rotations.

3.4 The focus of this strategic objective is to improve the efficient use of agricultural natural resources for food production, ensuring their sustainable use and management, reducing poverty and increasing wealth of people and industries dependant on natural resource-based agriculture.

3.4.1 Main objectives

The objectives will be obtained in the following three areas:

1. Coordination of Basic scientific research projects: The funding of the activities and monitoring of the results. This will be done by the ARC institutes, Universities and post graduate students. This will also include literature studies of international research project of CA. Research experts will play a key role in farmer field experiments in planning, design, observations, analyzing and interpretation results.

2. Coordination of practical application, adoption and implementation of CA in the maize production areas in South Africa for commercial, development and small scale farmers. This will include farmer's trials and demonstrations, supplier trails and inputs local advisors such as agricultural companies, fertilizer and chemical experts, seed company technical teams and local experts groups.

3. Coordination, editing, grouping and publishing information in popular agricultural magazines. The objective is to categorize information and focusing per area and soil type in order to help farmers selecting relevant information for specific application. Assigning and initiating information topics to agricultural journalists and cooperatives. The objective is to develop a Field Management Guide or a Field Use plan per area.

Coordination of Basic scientific research projects:

The criteria for evaluation of basic research projects:

- The main objective of the research project needs to promote Conservation Agriculture.
- Maize, in combination with rotating crops, should be the main crop under investigation.
- The treatments of the experiments should not include practices that will adverse

Conservation Agriculture e.g. burning, ploughing, disc or removing of organic material.

- The experiment need to be carried out with interaction with a CA farmer in field conditions. Part of the experiment may be glass house studies; however the results need to be applied practically.
- The application window of the results should include other areas.
- Duplication of research areas need to be minimized, however for pH-D students, the personal development as an expert in future will be important.
- The research project needs to address a relevant key problem area.

The objective is to monitor and measure where applicable, and analyze these research processes, and implement actions necessary to achieve planned results and continual improvement of CA processes.

Coordination of practical application, adoption and implementation of CA in the maize production areas in South Africa:

- Harmonize all relevant resources in support for the adoption of Conservation Agriculture.
- Identify and categorize production areas. Mapping uniform production areas with uniform soil and environmental conditions.
- Assess the status of the implementation of CA in the defined areas, referring to number of farmers, area (hectare), levels of implementation and active groups. Identify successful CA Procurers in each area. Categorize farmers in Commercial, Development and Small Holder Groups. The transforming strategies approach and information will differ for the various categories.
- The development of comprehensive databases per area about farmers, farmer groups, experts, contributors, suppliers and technical support teams.
- Promoting, stimulating and encouraging the forming of farmer groups. Identify innovators, producers that are hunger for change to CA and will share knowledge, experience and support each other. Determination of specific needs

for each group and make sure the technology ownership belongs to the group and that their specific needs are addressed within the framework of CA principles. The progress of adoption and implementation of CA will be community driven and process information will be owned by the people.

- Introduce mechanisms which provide incentives for farmers to change their production system to Conservation Agriculture. Encourage awards to successful innovators with international visits on condition that the individual invites a non CA partner with the potential to adopt CA during the trip.
- The Objective for Small Holder Farmers will be to transfer knowledge, demonstrate successful practices, lobbying financial recourses and sponsors for inputs, machinery and infrastructure expenses (fences). The approach will be to identify and respect the empowerment hierarchy and key role-players and decision makers to get commitment. This may be the Chief, Captain, or other recognized community leaders.
- Find solutions and practical adaptations, modifications of CA for specific and unique RSA conditions. Introduce international research and practical information to South African conditions on a farmer experiment base. Conservation tillage doesn't work well on sandy soils that tend to harden, or on soils that are at risk of water-logging. Specific research actions need to be conducted for successful implementation of CA in these areas. The current status need to be assessed and criteria for improvement defined and measurable indictors identified.
- Animal factor in crop production: Preventing or reducing gracing of crop residues. Removal of crop residues do has a negative effect on the yield of the next crop.
- Soft approach to encourage agricultural suppliers of machinery, seed, fertilizers, chemicals and finance to define CA goals & Objectives in their business policies. Promoting the concept of green, environmental friendly vicinity. Includes Conservation Agriculture as base concept for the adaptation of agriculture to the challenges of climate change.

- Encourage universities and training providers to include Conservation agriculture in curriculums for training and education of the next generation.
- Involve all relevant partners and share expertise. Sustainable natural resources management requires an integrated and holistic approach, including effective collaboration between all stakeholders at national, provincial and local levels.
- Facilitate and promote international expertise exchange with visits and inviting key research or practical farmers from areas similar to South African conditions. Expose South African Farmers to successful international groups.