AUSTRALIAN NUSSFIELD FARMING
SCHOLARS ASSOCIATION

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Topic: Sustainable Conservation Agriculture With No-Tillage

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1. EXECUTIVE SUMMARY

The Australian grains industry is growing in stature, value and diversity. There are thirty different grain crops grown in Australia, each with its special niche in cropping systems. Pulse and oilseed crops have expanded rapidly, although wheat still dominates grain production.

New pulse and oilseed crops in rotations with cereals, reduced tillage systems, larger machinery, and greater use of a wide range of herbicides, have had large impacts over the past two decades. Farmers are able to sow crops faster, plant larger areas and achieve higher yields.

However, there will be future growth in demand for cereals as the world population booms shortly to 7.67 billion in 2020. Projections by the International Food Policy Research Institute (IFPRI) suggest that the long-term trend for cereal prices is to continue to decline in real terms, although at a slower rate than in the past and for the area under crop production worldwide to increase.

Therefore the challenge for farmers today in both the developed and undeveloped worlds is for all to adopt modern farming practices (i.e. Conservation Agricultural systems, CA), which will allow them to remain viable and sustain world food needs.

With the decline of good quality available land for agriculture and this increased pressure for food production, farmers have to further improve the nature of our soil resource under our present management. This involves the halting and reversing of unnecessary degradation of our productive agricultural soils.

The purpose of my scholarship was to assess the viability and sustainability of Conservation Agriculture under no-tillage and research some of the critical methods and techniques.

Simply this means the introduction of suitable techniques to monitor and utilize our farming areas in a way that they remain productive and sustainable. This is achieved by using Conservation Farming. This being a holistic management systems approach to our cropping system which

- Increases soil organic matter and soil biodiversity,
- Enables higher infiltration rates and water storage capabilities,
- With crop rotations allows for a reduction in yield affecting diseases,
- Decreases the effects of long term tillage and degradation,
- Brings in considerable cost efficiencies in production.
- Increases the return to producers in the long-term
- Decreases effects of erosion,
- Increases carbon sequestration
What was experienced in most areas of the countries visited is that many forms of CA are being practised and are gaining varying degrees of results. Mostly in drier climates where input costs are of higher importance as potential returns are low was where CA was more widely used and in turn gaining the better results for both the producers back pocket and the general health of the soil.

The paper that follows will outline the practises used under no-tillage to gain higher profits and increased long-term productivity from our soils. The information in this paper has come from visits to Argentina, Brazil, Mexico, USA and Canada. Consultation with farmers, farm managers, service industry, marketing bodies, machinery manufacturers, research bodies and related conferences.

2. ACKNOWLEDGMENTS

Australian Nuffield Farmers Association – For instilling the faith in my scholarship.

Grains Research Development Corporation- for supplying the funds to assist in my scholarship

Sally West and young family in particular for supplying support and encouragement to fulfil the scholarship.
3. AIM

To establish under conservational agricultural practices using no-tillage whether or not we can continuously crop the soil to gain higher profits from our farming whilst limiting the increase of degradation bought about by conventional farming.

4. INTRODUCTION

The basic elements of Conservation Agriculture (CA) are: one pass seeding operations, little or no soil disturbance (no-tillage), not burning but retaining crop residues, crop rotation, permanent soil cover, integrated disease & pest management, chemical rotations and the use of leguminous green manure crops. Routine soil inspection and analysis and balancing nutrient and pH status are also very important component of the system.

CA is a holistic approach to farming. Applying the main elements is a principle road to sustainable agriculture which can achieve food security by; reserving soil degradation, reducing agrochemical use and contamination, improving food quality, and conserving, preserving and enhancing the quality of natural resources and biodiversity while increasing farmers net income and competitiveness, and sequestering carbon from the atmosphere.

The principles of CA have been thoroughly researched and implemented for many cropping systems in large farming areas worldwide, like USA, Canada, Brazil, Argentina, Paraguay, parts of Europe and the cropping lands of Australia. Improvements are many and at several levels such as: increased yields and farm productivity (i.e. lessen time of field applications), reduced use/reliance of External Farm Inputs per unit of product produced from each farming system, (i.e. Diesel Fuel, Fertilisers, Labour costs), increased soil organic matter levels and re-established microbial diversity and structure to the soil; allowing increased infiltration of rainfall and reduction of erosion effects to soil health.

The paper will detail some of the aspects of CA with relevance and application to some of the farming systems of Australia.
5. **SITUATION OF CONSERVATION AGRICULTURE IN THE WORLD**

No-tillage is practiced on about 70 million ha world wide (Table 1). Approximately 46 % is practiced in Latin America, 37 % in the United States and Canada, 13 % in Australia and 3 % in the rest of the world including Europe, Africa and Asia.

The countries that will probably experience the biggest expansion in CA in the coming years are Argentina and Brazil. The adoption of CA by the United States and Europe will be at a slower rate because of the mindset as subsidies hinder the creativity of the farmers. Australia is another continent where water harvesting and soil conservation because of economic reasons (saves labour, time, fuel, machine investment, compaction concerns) and existing farmer organizations, will experience a steady growth in area and quality. (Derpsch *et al.*, 2003)

**Table 1. Countries and area under No Tillage**

<table>
<thead>
<tr>
<th>Country</th>
<th>Area under No-Tillage in ha 2001/2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>22,410,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>17,356,000</td>
</tr>
<tr>
<td>Argentina</td>
<td>13,000,000</td>
</tr>
<tr>
<td>Australia</td>
<td>9,000,000</td>
</tr>
<tr>
<td>Canada</td>
<td>4,080,000</td>
</tr>
<tr>
<td>Paraguay</td>
<td>1,300,000</td>
</tr>
<tr>
<td>Bolivia</td>
<td>417,000</td>
</tr>
<tr>
<td>North India, Pakistan</td>
<td>350,000</td>
</tr>
<tr>
<td>South Africa</td>
<td>300,000</td>
</tr>
<tr>
<td>Venezuela</td>
<td>150,000</td>
</tr>
<tr>
<td>Chile</td>
<td>130,000</td>
</tr>
<tr>
<td>Colombia</td>
<td>70,000</td>
</tr>
<tr>
<td>Uruguay</td>
<td>50,000</td>
</tr>
<tr>
<td>Mexico</td>
<td>50,000</td>
</tr>
<tr>
<td>Ghana</td>
<td>45,000</td>
</tr>
<tr>
<td>Others</td>
<td>1,500,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>70,208,000</strong></td>
</tr>
</tbody>
</table>

**Source:** Rolf Derpsch, Conservation Agriculture and No-tillage Consultant, Paraguay, 2003. Congress on Conservation Agriculture.
6. ENVIRONMENTAL BENEFITS AND SOCIO-ECONOMIC IMPACTS

Environmental problems believed to be caused by agriculture include water contamination and tillage induced carbon dioxide (CO2) losses that contribute to the greenhouse effect.

CA, working in harmony with nature uses techniques that increase soil Carbon (C), can be of utmost benefit to society and can be viewed as “feeding and greening the world” for global sustainability. CA has through its impact on soil C enhanced ecosystem processes.

An ecosystem is a community of animals and plants interacting with one another and with their physical environment. Ecosystems include physical, chemical and biological components such as soils, water, and nutrients that support the biological organisms that live within them. Basic ecosystem processes in agriculture include the production of food, fibre and biofuels, the provision of clean air and water, natural fertilization, nutrient cycling in soils, mitigation of climate, pollination, genetic resources, recreational, cultural and social benefits and many other life support services. (Reicosky, D.C. 1998)

CA assists our agricultural ecosystem to help moderate weather extremes, mitigate natural drought and floods, protect streams and river systems (erosion), control agricultural pests, maintain biodiversity, generate and preserve soils, renew fertility, detoxify and decompose waste, contribute to climate stability, purify water and air and regulate disease carrying organisms. Therefore, soil C enhancement through CA plays a critical role in the harmony of our ecosystems.

Soil organic matter (SOM) is valuable for its role in physical, chemical and biological processes within the soil system. Soils high in C with crop residues on the surface are very effective in increasing SOM. (Reicosky, 2001). Increased SOM is commonly known to increase water holding capacity and infiltration and reduce soil erosion which is increasingly important for grain production in Australia. SOM also contributes to soil particle aggregation that assists plants in root development.

Prospects of achieving global environmental goals through increased emphasis on land management depend heavily on the extent the rural sector and rural communities can capture real value from the provision of global environmental services. This may involve removing barriers for farmers adoption of conservation practices, rewarding farmers for environmental management and developing and maintaining specialty markets for “environmentally friendly” produce.

Community based natural resource management initiatives, combining agricultural productivity growth and improved environmental quality are good initiatives. However, these farmer led initiatives require institutional support from local, national and even international institutions. This support needs to be in financial, research support and technical assessments of the quality and value of the environmental services.

Farmers are the primary soil managers who have a responsibility to maintain SOM for the environmental benefit of the global population.
7. SOIL CARBON MITIGATION

Typically agricultural soils contain 1-4% C on mass basis which is regarded as relatively small. Agricultural production systems can play a significant role in soil C sequestration because they contain a large amount of soil C that can partially offset C emission from burning fossil fuels.

Increased soil C can lead to better infiltration and fertility, less wind and water erosion, minimized compaction, enhanced water quality, decreased C emissions, impeded pesticide movement and overall enhanced environmental quality. Recent studies that measured short-term C losses from various tillage methods indicated major C losses immediately following intensive tillage (Reicosky and Lindstrom, 1993). It was also concluded that there was direct correlation between depth of tillage, soil disturbance and the level of C losses to the atmosphere from the soil (Reicosky, 1998).

The main benefit of CA is the immediate impact on SOM and soil C interactions. Direct seeding methods for sustainable production have the potential to sequester more C in the soil than farming emits through land use and fossil fuel combustion and thus may restore soil C loss as a result of traditional farming practices. Enhanced soil C management also offers economic benefits through reduced labour, time savings, reduced machinery requirement and fuel savings.

What can be noted from Table 2 where long term no-tillage has been evaluated for CO2 tie up in Saskatchewan, Canada is that in the latter 7 years of the 20 year period more CO2 tie up has taken place. It was noted by the source that in the latter years there were favourable production conditions hence the additions to carbon levels were significant.

<table>
<thead>
<tr>
<th></th>
<th>Tonnes C/ha</th>
<th>% of Native</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native</td>
<td>84.1</td>
<td>100</td>
</tr>
<tr>
<td>Conventional till</td>
<td>57.3</td>
<td>68.1</td>
</tr>
<tr>
<td>Zero till</td>
<td>65.2</td>
<td>77.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gain in C using zero till</th>
<th>Tonnes C/ha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average over 13 years</td>
<td>0.61</td>
</tr>
<tr>
<td>Average over 20 years</td>
<td>1.27</td>
</tr>
</tbody>
</table>

Source: Jim Halford 2001

As Australian farmers, we need to keep C sequestering in mind, as this will be the “hot topic” of global agriculture in the coming years. Enhanced soil C management is a win-win situation as agriculture wins with improved food and fibre production systems and sustainability and society wins with the enhanced environmental quality.
8. WATER HOLDING

Australia is a very dry continent with over 40% of the land receiving less than 300mm of annual rainfall. There are also large variations of soil types in the cropping areas, being:

(i) Black/Brown self mulching clay loams-high water retaining.
(ii) Red Loam soils-Moderate water retaining.
(iii) Sandy soils-very poor water retaining.

(Hubbard, RA., 2003)

Soil moisture retention in dry regions is the single most critical factor in the farming system. The retention of residue allowing a buffering capacity on soil temperature and the increasing of SOM facilitate improved soil structure thus infiltration will be increased aiding the water holding potential of the soil. The soil must have the ability to absorb as much water as possible in dry regions and with high SOM the soil will have the better hydraulic conductivity- the soils ability to absorb water.

The water infiltration and holding capacity was best shown by some residue retaining trials under no-tillage systems at CIMMYT headquarters in Mexico. These trials were long rainfed trials of some 12 years. (Figure 1)

![Figure 1. Left - residue removed, right - residue retained on a wheat/maize rotation. Trials conducted on a 0.5% gradient.](image)

Figure 1 shows that there is a vast difference between the crop health on the retained residue.

Combined with the increased SOM there will be a natural increase in microbial activity (particularly earth worms), through increased animal passages creating enhanced porosity. This will be further discussed in this report.

With CA, farmers reduce the risk of harsh environments and are better placed to sustainably prosper in the future.
9. INCREASING SOIL BIODIVERSITY

The rhizosphere is characterized by intense microbial activity, and represents a close relationship between the plant, soil and soil organisms. Most of the nutrient cycling, roots and biological activity are found in the top 20-30cm, commonly known as the root zone.

Plants provide the carbon food source for soil organisms that bind the soil particles into aggregates and recycle soil nutrient. Soil provides the habitat, water, and mineral nutrients for both soil organisms and plants. This equates to any factor that influences the quality and amount of residue and root decay, will affect the biological community in the soil.

Vesicular-Arbuscular Mycorrhizal (VAM) fungi are present in soils. These penetrate the cells of the root without harming the plant, from this root the microscopic hyphae extend like a network of silk threads through the soil. VAM fungi then are considered a highly effective transport system between the soil and the plant moving water and nutrients to the plant in return for direct access to the carbon rich products of photosynthesis. VAM fungi are best known for increasing the uptake of nutrients like phosphorous, calcium, zinc and copper.

Earthworms are often considered as very favourable to increase soil aeration, water infiltration, nitrogen availability to plants, and the microbial activity of the soil. Earthworms not only provide tunnels that assist ease of root growth and water infiltration but it has been found that these tunnels have higher concentrations of nitrifying bacteria than the soil outside the tunnel. This will again encourage root growth in these tunnels. Earthworms feed off the decaying plant material fungi, protozoa and bacteria leaving behind sticky secretions which bind small soil particles together into larger aggregates further improving soil structure.

To manage cropping systems to enhance the biological activity of soil can be achieved simply by:

(i) No-Tillage (NT) holds these pores and tunnels together that were constructed by soil animals, which maintains the water holding capacity and nutrient exchange capacity of the soil.

(ii) Crop residues under NT and rotations will have a direct effect on keeping the feeding ground available for these activities to continue.

(iii) Rotations can be managed collectively for disease implications in the crop as well as for residue management. For example, a high residue crop (wheat) can follow a low residue crop (peas, lupins, canola).

It is found that the more diverse the soil community the more flexible the soil. This means the soil has the ability to grow a number of crops, and is resilient to drought and low nutrient conditions. (Clapperton, 2003).
10. SOIL COMPACTION

Soil compaction is an issue possibly being addressed in a most advanced form within Australia alone. The spectrum of soil compaction has been perceived to threaten the acceptance and success of NT farming systems.

Li et al., (1999) evaluated the impact of compaction from wheel traffic on a NT soil that had not been trafficked for 5 years in Queensland, Australia. A tractor of 49kN rear axle weight was used to apply traffic at varying wheel slip on a clay soil and varying residue cover to simulate effects of traffic typical of grain production in the northern Australian grain belt. A rainfall simulator was used to determine infiltration rates. Wheel traffic considerably reduced time to ponding. Non-wheeled soil had 4-5 times greater infiltration than wheeled, irrespective of residue cover. Where there was no compaction from wheeled traffic, residue had a greater effect on infiltration capacity, with steady infiltration increasing with the increased proportion of residue cover. Residue cover, however, had much less effect on infiltration when wheeling was imposed, thus demonstrating that infiltration under a controlled traffic zero-tillage system was similar to that of virgin soil. When a medium sized tractor wheeled the soil infiltration was reduced to that of long term cropped soil. These results suggest that wheeled traffic (compaction), rather than tillage and cropping have a major role in determining infiltration.

There also is the same concern for the root access to the soil through these compacted zones. Controlled traffic is now becoming more adopted in cropping systems, where permanent tracks are used to allow no traffic on the fields that are growing the crop. With the use of GPS systems of guidance to add accuracy there is a symbiotic response to reduced labour, input costs and the better soil structure to indeed grow the crop with increased infiltration.

It has become evident that machinery is finally starting to become manufactured to cater for the compaction issues cropping systems now face. This has included the introduction of firstly tracks and now tractors with the ability to be set on a fixed width system of controlled traffic of say 2-3 m widths. (Figure 2)

These developments relieve from the farmer who wishes to adopt these techniques as previously it has been a lonely modification process of existing equipment which can waiver warranty.

Figure 2. 3 m track control traffic developed 550hp caterpillar tractor as seen in Canada.
11. INTEGRATED PEST MANAGEMENT IN NO-TILLAGE SYSTEMS

In NT systems, Integrated Pest Management (IPM) can be better developed than in conventional cultivation systems. The dead plant cover from previous crops, left on top of the soil, serves as a refuge for huge amount of invertebrate and micro fauna, and, if some of these can be economically important crop pests, many of the others are in fact beneficial organisms, that include nutrient recyclers and pest predators. Earthworms, spiders, millipedes and adult and larval scarab beetles, amongst other invertebrates, are responsible for greatly increased drainage and soil ventilation in no till systems, due to the tunnels and galleries that are excavated in the soil, up to depths of three metres, which permits a highly improved circulation of air, water and nutrients through the soil levels. (Pruett, 2003).

Generally speaking in NT systems, the diversity of fauna, especially anthropods, is much greater than in conventional tillage (CT) systems. A NT agroecosystem is inherently much more stable than an agroecosystem in CT, where the upper soil temperatures can rise to 50 degrees centigrade, with low humidity, were as in NT the soil remains at a much lower temperature whilst retaining humidity for an extended period of time. In CT systems, especially during crop establishment, there is little to no ground cover, for natural enemies of crop pests and the other fauna, so important for nutrient recycling. This same fauna provides alternative prey for insect pest predators.

Amongst the main pest problems in NT systems are weeds and insects. The principle insect damage can occur during plant emergence and development, such as cutworms and locust. The incidence is high when previous crop residues and weeds are green supplying a feeding ground for pests. When the crop emerges then these pests can turn there attention to young emerging plants. In the NT systems in Australia usually the crop is seeded directly after rain thus an application of glyphosate and the crop is seeded onto green weeds, so it is important to include a synthetic pyrethrum to the tank mix of glyphosate. If the knockdown has been applied 2 weeks prior to seeding this insecticide may not be necessary as all weeds and previous crop may be dried off.

12. ECONOMIC ASPECTS OF CONSERVATION AGRICULTURE

Apart from the soil improvement and agronomic advantages of NT there are also many economical benefits associated.

Environmental and health problems are central to many agricultural policy debates; the progress towards halving hunger and poverty in developing countries has been slower than expected, and investment into rural areas has dropped to an all time low. Against this back drop The World Bank forged a new Rural Development Strategy.

One of the supporting studies from the FAO/World Bank study of poverty and farming systems, noted the potential of CA in several regions of the world as one example of win-win development approaches that generate productivity and environmental dividends.

The widespread perception of positive economic benefits of CA is in marked contrast to the lack of rigorous data on its farm income effects, especially in low and middle income countries. The largest set of data comes from large-scale commercial farming in North America and Australia, where on average there exists a small effect stemming largely from a reduction in field costs. This can vary across locations, scales of
adoption, (partial adoption will increase machinery costs) time frames and fuel prices (The cost advantage of CA increases with higher fuel costs).

Not withstanding the profitability of CA, there is also perception in some areas that CA increases production risk. However, data pertaining to this is extremely scarce. There is also some evidence in many areas that under conditions of good management, CA reduces inter-seasonal yield variability in low rainfall areas, principally by limiting yield reductions in dry years. This may only be achieved under good management, meaning stringent weed and pest control and above all timeliness of operations. There would also be the issues of increased income from environmental effects in some countries as the U.S.A, from the conservation programme in the Farm Bill. In parts of Western Europe the value of environmental services of well-managed agriculture can be of the same order of magnitude as the gross value of agriculture production itself.

CA in principle is an economical-environmental win-win development approach. Therefore, the collection and analysis of technical and environmental productivity data on CA is high in priority, especially in farming systems where the adoption of CA has been slower than expected.

13. PROMOTING CONSERVATION AGRICULTURE

The traditional view of agricultural technology development, dissemination and adoption has been that of a linear process. In this process researchers develop new knowledge or technological options, these are then passed to extension agents and then on to farmers.

However CA is a complex set of technologies that requires a change in the whole farming system, ranging from seeding equipment, seeding time and method, fertilizer application techniques and times, residue management, modified weed and pest control management, different harvest procedures, crop rotations and possibly the use of green manure crops and changes in the way that any fallow periods are managed.

CA needs an innovative system, involving a network of different agents and institutions working together with a dynamic flow of information, all participating in the development and testing of different aspects of technological development; some doing the actual development, others providing feedback.

The nature and composition of the network depends on the complexity and state of maturity of the technology it develops. Innovative systems bring together the knowledge, information and expertise of numerous people with different experience and expertise and focus on overcoming a problem or set of problems. It appears that the key factor to success is the unimpeded flow of information and the central role played by innovative farmers. Farmer to farmer communication and information exchange is the principle method of technology transfer and adoption. Figure 3 shows a graphical example of an innovative network to implement CA.
Figure 3: An example of the innovation network
14. MACHINERY AVAILABLE

There is no one particular machine suitable for all conditions but as NT becomes more prominent in world agriculture so to is the development by machinery companies and their equipment. No longer do people in developed countries have the lack of available machinery as an excuse. In the past many innovative farmers have had to build or modify existing machinery, which still maybe needed today.

NT machinery comes in many shapes and forms depending on the residue needed to pass through, soil types and conditions, humidity, the agronomy requirements of seed placement and the type of crop being seeded. They possibly can be categorized in 2 main formats, that of Coulter seeding (Single/Double) or the tyne seeding. The coulter or disc seeding system is where the seed is sliced into the soil either with one disc or two disc’s working slightly offset (Figure 4).

Figure 4. Coulter seeding machinery
The system in Figure 5 has been regarded as being able to handle/cut through the most residue and is very dominant in high rainfall areas of Argentina and Brazil. The disadvantages seen in this system is the slow ability to rehabilitate compaction layers, the lack of tilth under seed row, and in some soils side smearing of the soil which limits lateral root development.

The tyne system (Figure 6) achieves seeding through the use of a narrow knife-style point that minimally disturbs the soil but can supply suitable tilth under the seed for primary root development with minimal side smearing for lateral roots. The tyne system under humid conditions will not travel through the residue the coulter seeder will, providing the disc on the coulter remains sharp. With a majority of the dryland conditions in Australia growing wheat, the tyne system is more widely used as large residues are not a problem.
There has been work conducted on row spacings and there is no common answer for preference in a general sense. The choice for NT equipment really has to remain, the choice of the individual farmer for the reasons or the conditions that he/she is working with. It should be noted that the wider the spacing the larger amount of residue to be dealt with, the less soil disturbance resulting in lower weed germination, the better utilizing of water in dry conditions and the ability for better chemical contact on competition weeds. It must be considered how wide can the spacing be under the conditions before potential yield is reduced. Often seeding equipment choice can vary from neighbour to neighbour not dissimilar to that of conventional farming neighbours.

Through Canada, USA, Argentina, Brazil and Mexico it was found that all machinery companies are mainly introducing new technology for machines used for NT. These companies are only responding to the increasing demand of the farmer. This varies from developing countries using animal traction to the developed countries using machinery, drawn by 500hp, up to 20metres wide.

The ability to apply all necessary nutrients close to or away from the seed in one pass operation is continually a concern for adopting farmers. Most earlier innovative farmers have had much expense and yield loss in trialling varying systems but today’s adopters have the advantage of this experience. Farmers must continually look to improve their systems and in doing so need to take the time to research their changes either through trial work, other farmers experiences, researchers trial work and also investigate what machinery companies are releasing because somewhere in the world a large number of farmers are asking for this technology and just maybe it will have some merit for your system.
15. CONCLUSION

Global goals of policy makers are, increasing cereal harvest from 2 billion tonnes to 3 billion tones by 2030, tackling resource threats (e.g. drought, soil degradation) and addressing health threat issues. Farmers goals are for food security, increased profit in the present, lower costs of production, lower production risk, a higher social standing with regards to environment and of course more leisure time.

Mechanical tillage around the world and indeed in Australia has caused declines in soil quality and plant production. This has created large areas of productive soils that have become fragile (prone to desertification: low organic carbon, soil quality/fertility, and biomass productivity) due to continuous cultivation. CA as opposed to plough based tillage systems, prevents and eventually reverts these declines, due largely to alteration of soil functions and processes. The complexity amongst NT effects on soil and land productivity world-wide is the agent for widespread popularity and acceptance of the system in the world. NT’s exceptional importance to carbon sequestration, fertility management, erosion control and potential production, is the largest influence on offsetting desertification.

CA has no remedy that is a fix one fix all. CA has to be applied to each environment and soil conditions as required but keeping in mind that working with the residues and not against them is the key.

Substantial efforts are still required to increase the adoption and growth of NT to large scale during the coming years as there are still social, economic, and policy constraints that restrict the rate of progress of NT.

To ensure prolonged adoption of CA we must form alliances and partnerships, among farmers, conservation groups, Government bodies and researchers alike. The education of its benefits to consumers is of high importance as with all agriculture if you eat, you are involved.
16. DEFINITIONS

**Conservation Agriculture:** Comprises of the universal principles of permanent soil cover, direct seeding, minimum soil disturbance and annual crop rotation.

**No-tillage:** The seeding of the crops with no soil disturbance, and no mechanical preparation.

**Reduced Tillage:** Minimal soil disturbance in preparation and seeding.

**Conventional Tillage:** Full soil inversion in preparation and in seeding.

**Carbon Sequestration:** Process by which you increase soil carbon content through conservation agricultural methods.

**Soil Organic Matter:** Level of organic matter remaining in the soil.

**Desertification:** The sterilisation of soil caused by high levels of degradation through long term mechanical soil inversion.
17. REFERENCES


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