What is Conservation Agriculture?

CA is 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. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes. CA is characterized by three principles which are linked to each other, namely:

1. Continuous minimum mechanical soil disturbance.
2. Permanent organic soil cover.
3. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.

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.

Excessive tillage of agricultural soils may result in short term increases in fertility, but will degrade soils in the medium term. Structural degradation, loss of organic matter, erosion and falling biodiversity are all to be expected. (T Friedrich).

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 is still being gained with this new approach to agriculture and FAO has supported the process for many years.

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 macropores leading from the soil surface straight to the subsoil and allowing fast water infiltration in case of heavy rainfall events.

Keeping the soil covered and planting through the mulch will protect the soil and improve the growing environment for the crop. This picture shows soya planted into wheat straw (a good rotation; by direct planter (minimal soil disturbance), without removing the previous crop residue (permanent soil cover). Good CA. (J.Benites).

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.

Burning crop and weed residues destroys an important source of plant nutrients and soil improvement potential. The phytosanitary motives for burning and ploughing can better be achieved by integrated pest management practices and crop rotations. (FAO).

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. 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. Particularly in Brazil the area under conservation farming is now growing exponentially having already reached the 10 million hectare mark. Also in North America the concept is widely adopted.

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, chelation 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 rotation**

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.

A three-row no-till planter planting through a cover crop flattened by a knife roller. (T. Friedrich).

More information in Tools, machinery and equipment

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.

Cover crops need to be managed before planting the main crop. This can be done manually or with animal or tractor power. The important point is that the soil is always kept covered. (FAO).

The effects of soil cover:

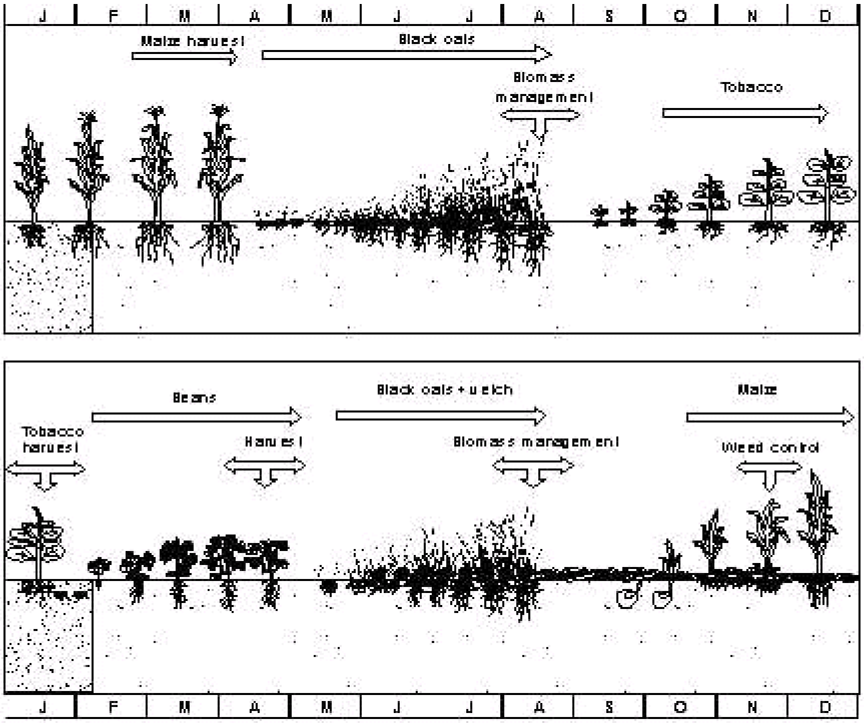
- Improved infiltration and retention of soil moisture resulting in less severe, less prolonged crop water stress and increased availability of plant nutrients.
- Source of food and habitat for diverse soil life: creation of channels for air and water, biological tillage and substrate for biological 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 rotations

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 carry over of crop-specific pests and diseases from one crop to the next via crop residues



An example of crop rotation to maintain soil fertility and break pathogen carry-over

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 biopores 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 biota symbionts 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 conditions.

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 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.
Manual labour for soil preparation is back-breaking and unnecessary. Should the supply of labour be reduced, through sickness or migration, then the system can quickly become unsustainable. (T.Friedrich).

Agronomic benefits

Adopting conservation agriculture leads to improvement of soil productivity:

- Organic matter increase.
- 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.
A soya plant with deformed root system due to compaction. The roots show a marked tendency to lateral development with few vertical roots to explore other soil strata. (D. McGarry).

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.
Maintaining soil cover will reduce erosion with the consequent loss of soil fertility, soil compaction, and, eventually, landscape change. (A. Calegari).

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 few profit from the change and 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.

Initial nervousness about switching from plough-based farming to CA can be ameliorated by forming farmer groups to exchange ideas and gain knowledge from more experienced practitioners. (A.J. Bot).

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.

Adapted from: http://www.fao.org/ag/ca/1c.html [Accessed 21 August 2006]