Conservation of natural resources for sustainable Agriculture

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No mechanical soil disturbance
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Introduction

Crop production in tropical and subtropical areas in the world has been influenced heavily by European developments. Advances in machinery and equipment were introduced in tropical areas without critically testing and validating them first. We know now that discs are not the most suitable equipment to be used under tropical conditions. Traditionally, tillage forms an important part of crop production. The principal motive to prepare the soil is to facilitate planting and accelerate seedling growth. Besides that, land preparation is considered necessary to obtain a uniform crop, without the interference of weeds. Still in a lot of places in the world a bare soil is considered pleasant to the eyesight and a farmer with nicely ploughed fields is considered a good farmer.

The passage of machinery, and the continuous use of ploughs and harrows at the same depth and during periods of high moisture content, creates compact sub-surface layers known as plough pan or harrow pan. These have damaging effects on the development of plant root systems, oxygen availability and soil water movement. The consequences are disastrous. The rate of water infiltration is drastically reduced with a simultaneous increase in surface runoff, loss of soil, nutrients, organic matter, calcium and seeds. The activity of soil biota is also negatively affected. Over the last decades, farmers have been expressing their worry/preoccupation about soil erosion, labour, input costs caused by heavy ploughing. Some farmers have tried to reduce the intensity of land preparation, but often ended up facing problems like low germination, low productivity and high weed infestation. The developments in research have resulted in adaptation of seeding machinery, crop rotation with cover crops and improved herbicides. This has allowed farmers to reduce, and even eliminate land preparation activities and at the same time maintain or improve yield levels.

At the moment alternative options to soil tillage exist, like conservation agriculture, which breaks with former beliefs. Conservation agriculture maintains the agricultural lands of the world in a sustainable way. In order to be able to transfer and realize this technology, it is necessary to understand all its different technical aspects.

Table 1 Advantages and disadvantages of conventional tillage and conservation agriculture

<table>
<thead>
<tr>
<th>Conventional tillage</th>
<th>Disadvantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>prepare a seedbed</td>
<td>loss of soil moisture</td>
</tr>
<tr>
<td>manage crop residues</td>
<td>limits water infiltration through surface sealing</td>
</tr>
<tr>
<td>incorporate fertilizers and agro-chemicals</td>
<td>destroys the soil structure</td>
</tr>
<tr>
<td>control weeds</td>
<td>increased erosion risk</td>
</tr>
<tr>
<td>decompact dense soil layers</td>
<td>increased operational costs</td>
</tr>
<tr>
<td>increase water infiltration</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conservation agriculture</th>
<th>Advantages:</th>
</tr>
</thead>
<tbody>
<tr>
<td>conserve the soil</td>
<td>increases organic matter</td>
</tr>
<tr>
<td>soil moisture retention</td>
<td>increases water</td>
</tr>
<tr>
<td>improve the soil productivity</td>
<td>improves the soil structure</td>
</tr>
<tr>
<td>reduce machinery costs</td>
<td>increased crop yields</td>
</tr>
<tr>
<td>reduce labour input</td>
<td>allows more time off for other activities</td>
</tr>
<tr>
<td></td>
<td>more cost-effective</td>
</tr>
</tbody>
</table>
Main principles of conservation agriculture

Conservation agriculture systems are systems that utilize soils and crops with the aim to reduce the excessive mixing-up of the soil and maintain the crop residues on the soil surface in order to minimize damage to the environment.

In this way, it will:

- provide and maintain an optimum condition of the root-zone to maximum possible depth for crop roots to function most effectively and without hindrance, in capturing high amounts of desired 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 streamflow, 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:

- no mechanical soil disturbance
- permanent soil cover, especially by crop residues and cover crops
- crop rotation
**No mechanical soil disturbance**

Direct seeding involves growing crops without mechanical seedbed preparation or soil disturbance since the harvest of the previous crop. The term direct seeding is used synonymously with no-till farming, zero tillage, no-tillage, direct drilling, etc.

No-tillage involves slashing the weeds and previous crop residues or spraying herbicides for weed control, and seeding directly through the mulch. All crop residues are retained, and fertilizer and amendments are either broadcast on the soil surface or applied during seeding.

**Effects:**

- minimal destruction of soil structure through pulverisation, compaction and/or plough pan development
- slower mineralization of soil organic matter through less exposure to climatic elements and soil micro- and macrofauna
- no disturbance of worms and other soil inhabitants, maintained soil biodiversity and balanced activity and food web in the soil including natural predation
- no breaking of roots
- better infiltration and circulation of air and water into and through the soil profile through maintained biopores and vegetative cover and optimal rooting
- reduced evaporation from bare soil surfaces
- soil regeneration rate through mineralization and decomposition and re-structuring higher than soil degradation through loss of porosity and soil particles (erosion) and loss of plant nutrients (fertility)
- improved nutrient retention and availability for plant growth and reduced leaching of nitrogen and other nutrients

**Means and practices:**

- no ploughing, subsoiling, harrowing etc.
- use of direct seeding through crop residues
- no incorporation of crop residues into the soil
- permanent bed planting
- use of crop rotations, balanced biodiversity and pesticides for weed/pest control instead of ploughing or using high rates of chemicals that endanger soil life and disturb the soil web and ecological processes including the hydrological cycle and water quality

[More information in Tools, machinery and equipment](#)
**Permanent soil cover**

A permanent soil cover is important to:

- protect the soil against the impact of rain and sun,
- 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.

**Effects:**

- 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, habitat and energy 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 killers, etc.
- optimization of crop rotations in spatial, timing and economic terms
- targeted use of herbicides for controlling cover crop and weed development
**Crop rotation**

Rotation of crops is not only necessary to offer a diverse "diet" to the soil microorganisms, but as they are rooting at different soil depths, they are capable of exploring the 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.

**Effects:**
- ☺ 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 form, size and depths)
- ☺ better distribution of water and nutrients through the soil profile
- ☺ exploration for nutrients and water of the whole soil profile by roots of many different plant species resulting in an optimal 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

**Module on Cover crops and crop rotation**

Plate 3
Hairy vetch (*Vicia villosa*) is not only an effective cover crop for soil improvement, but attractive to honey bees as well.

*S. Vaneph*
Advantages and disadvantages

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 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 be observed:

- Time saving and thus reduction in labour requirement
- Reduction of costs
- Higher efficiency

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

The substitution of conventional tillage by conservation agriculture allows a more even distribution of labour over the year, because of the elimination of ploughing and harrowing activities and the use of cover crops and herbicides. The example in figure 1 shows no differences in labour requirements in January and February, which is harvest time of beans in Paraná. Under conservation agriculture, cover crops are sown in April and managed in September, which requires some hours of fieldwork. The next bean crop is sown in October/November, resulting in labour peaks for the conventional system, as the land needs to be prepared. Also more labour is needed in the conventional system for weeding activities in December. The total labour saved in this situation was 50 hours per hectare.
Not only the total time required for agricultural production is reduced, but also the number of activities is reduced as is demonstrated in the example in table 2.

Table 2. Mechanized operations and the time required (hours/ha) for each of them under different production systems (Rego, 1998).

<table>
<thead>
<tr>
<th>Operation</th>
<th>Conservation agriculture</th>
<th>Conventional tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knife roller</td>
<td>0.89</td>
<td>-</td>
</tr>
<tr>
<td>Direct seeding</td>
<td>0.76</td>
<td>-</td>
</tr>
<tr>
<td>Spraying</td>
<td>1.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Harvest</td>
<td>0.93</td>
<td>0.93</td>
</tr>
<tr>
<td>Ploughing/disking</td>
<td>1.27</td>
<td>1.37</td>
</tr>
<tr>
<td>Levelling</td>
<td>1.38</td>
<td></td>
</tr>
<tr>
<td>Conventional planting</td>
<td>0.89</td>
<td></td>
</tr>
<tr>
<td>Earthing</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>3.78</td>
<td>6.17</td>
</tr>
</tbody>
</table>

Especially in areas where (family) labour is becoming a constraint, because of migration or death, conservation agriculture is a good option for farmers. The reduction in on-farm labour requirement allows farmers to:
- extend the cultivated area,
- hire themselves out in off-farm employment,
- diversify their activities, including processing of agricultural products, or
- reduce the cultivated area, because of increased production and allow the marginal area to regenerate.

Table 3 gives a simple overview of the labour requirements, using animal traction or tractor in land preparation activities. Especially in the case of animal traction the reduction in labour when applying conservation agriculture is high: 86%. Time required to prepare the land using a tractor is reduced with 58% under conservation agriculture.

Table 3. Time requirement for land preparation activities under conventional tillage and conservation agriculture (Skora Neto, 1993).

<table>
<thead>
<tr>
<th>Operations</th>
<th>Conventional tillage (hours ha⁻¹)</th>
<th>Conservation agriculture (hours ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ploughing</td>
<td>1.5</td>
<td>Knife roller</td>
</tr>
<tr>
<td>Harrowing (2x)</td>
<td>1.4</td>
<td>Spraying</td>
</tr>
<tr>
<td>Total</td>
<td>2.9</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.2</td>
</tr>
</tbody>
</table>
Animal Traction | Animal Traction
---|---
Ploughing | 25 | Knife roller | 3
Harrowing (2x) | 5 | Spraying | 1.5
Furrowing | 3 | Total | 4.5
Total | 33 | Total | 4.5

In production systems that use manual labour or animal traction physical exercise of the farmer (i.e. walking in the field) is also reduced considerably, as is shown in table 4.

Table 4 Covered distances (km) by man for the cultivation of one hectare of maize, using animal traction under conservation agriculture and conventional tillage (Melo, 2000).

<table>
<thead>
<tr>
<th>Operation</th>
<th>Conservation agriculture</th>
<th>Conventional tillage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ploughing</td>
<td>-</td>
<td>40</td>
</tr>
<tr>
<td>Harrowing</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td>Furrowing</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Planting</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fertilization</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Knife roller</td>
<td>7.5</td>
<td>-</td>
</tr>
<tr>
<td>Weeding</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td>Nitrogen application</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Bending over of the cobs</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Harvest</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Total distance (km)</td>
<td>57.5</td>
<td>145</td>
</tr>
</tbody>
</table>

Besides a reduction in time required for field activities, the costs for operation and maintenance are also reduced (figure 2). Fuel and lubricants are reduced and also wear and tear of tractors, machineries and other equipment is less, resulting in lower maintenance and repair costs, and an increase in life span of the equipment. As ploughing activities are eliminated, farmers do not need heavy machinery or tractors, resulting in lower investment or write-off costs.

Generally, the costs for inputs are a bit higher in conservation agriculture compared to conventional tillage, due to cover crop seeds and agrochemicals.

One of the most exciting recent developments has been the response of rice farmers to conservation agriculture in Southeast Asia. According to Ardjasa (1994) small holder farmers in Indonesia are realizing 25 percent saving in labour, 65 percent savings in land preparation costs, 28 percent savings in irrigation water per cropping cycle and 2-3 weeks time saving for land preparation. In conventional preparation of paddies 30 percent of the water is used in the ploughing and puddling process. A substantial amount of this water is lost into the canals during this process resulting in soil and water loss and water pollution. The small farmers in Indonesia rent the equipment to plough and as availability is limited they often have to wait, sometimes missing a cropping cycle. Together with the 2-3 weeks real savings in time to prepare the land for planting conservation agriculture will help move production from the current average of 1.4 crops...
per year towards a realizable two or even three crops a year. Similar results are being observed in the Philippines, Thailand and India (Hebblethwaite, 1997).

In general, conservation agriculture can produce equivalent or higher yields compared to conventional tillage systems (Figure 3).

![FIGURE 3](image1)

Immobilization of nitrogen might cause a reduction in maize yield during the first years of conservation agriculture, but this can be overcome with the application of nitrogen fertilizer.

![FIGURE 4](image2)

Based on research data, maize can produce a yield with oats, lupine and vetch as a cover crop (without fertilization), which is comparable or higher to those obtained with conventional tillage and a fertilizer treatment of 90 kg ha$^{-1}$.

The yield increase in these cases was highly correlated with the phosphorus content of the leaves and the phosphorus availability in the soil. This occurred because of higher moisture content in the soil under the mulch layer, which led to higher phosphorus uptake by plant roots. Improvements in crop growth and vigour are due to direct and indirect effects. Direct effects are due to improvements in nutrient and water content, as
indirect effects are due to favourable rooting environment and possible weed suppression and reduction in pests and diseases.

![Figure 5](image-url) Maize yield after different cover crops, under conservation agriculture (green) and conventional tillage (brown) with and without nitrogen fertilizer (Calegari, ..).

Crop yields under conservation agriculture are less variable through the stabilizing effects of favourable conditions of soil properties and microclimate.

Overall, with equal or slightly higher yields and reduced costs, the farm income increases under conservation agriculture.

![Figure 6](image-url) Economic result of different production systems in Santa Catarina (conventional tillage = left and conservation agriculture = right) for four different production systems (Heiden, 1999).

More information in Module Farm management and economics
**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 of the organic matter content of the soil. In the beginning this is limited to the top layer of the soil, but with the years this will extend to deeper soil layers. Organic matter plays an important role in the soil: fertilizer use efficiency, water holding capacity, soil tilth, rooting environment and nutrient retention, all depend on organic matter.

Figure 7 shows that a reduction in nitrogen fertilizer can lead to higher crop productivity, probably through improved soil properties through an increase in organic matter content.

![Figure 7](image.png)

The increased organic matter content together with soil cover leads to increased water holding capacity of the soil.

**Plate 5**
The amount of soil moisture "saved" by the soil cover from evaporation can make the difference between a real harvest or a wilted crop. *A.J. Bot*

As a consequence less irrigation water is needed to irrigate the same crop as is shown in table 5 for the Brazilian Cerrados. Especially in areas with lack or scarcity of (irrigation)
water, conservation agriculture can result in a larger area irrigated with the same amount of water.

**Table 5 Economy of irrigation water through soil cover (Perreira, 2001).**

<table>
<thead>
<tr>
<th>Percentage of soil cover</th>
<th>Water requirement (m$^3$ ha$^{-1}$)</th>
<th>Reduction in water requirement (%)</th>
<th>Number of times irrigated during season</th>
<th>Number of days in between irrigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2660</td>
<td>0</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td>50</td>
<td>2470</td>
<td>7</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>75</td>
<td>2090</td>
<td>21</td>
<td>11</td>
<td>8</td>
</tr>
<tr>
<td>100</td>
<td>1900</td>
<td>29</td>
<td>10</td>
<td>9</td>
</tr>
</tbody>
</table>

More information on the effects of conservation agriculture on soil properties is presented in the modules "Soil fertility", "Soil moisture" and "Organic matter and biological activity".
**Environmental benefits:**

- Reduction in soil erosion, and thus of road and power plant maintenance costs
- Improvement of water quality
- Improvement of air quality
- Biodiversity increase

Residues on the soil surface reduce the splash-effect of the raindrops, and once the energy of the raindrops has disappeared 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, of which the latter reduces evaporation.

Soil erosion is reduced close to the regeneration rate of the soil or even adding to the system as was found by Debarba and Amado, 1997 in the cropping system oats+vetch/maize (figure 8).

![Figure 8](image)

**Soil loss due to water erosion (corrected with soil regeneration = 1.7 t ha⁻¹ yr⁻¹) for different maize cropping systems (Debarba and Amado, 1997).**

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 sooner replacement.

![Plate 6](image)

**Plate 6**
Precious soil is lost for agriculture when deposited in the ocean and can even cause an ecological disaster for local fishermen.
FAO
Bassi (2000) reports significant reductions of water turbidity and the concentration of sediments over a period of ten years (1988-1997) in different catchment areas in southern Brazil. The reductions varied between 50 and 80 percent, depending on associated soil types predominating in the areas. These reductions are due to increased perennial crops (banana and pasture) on hillsides, thus reducing the erosion process. Total sediment loss was decreased with 16 percent and consequently, this reduced the cost of fertilizers with 21 percent.

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 .

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. Data obtained in Chapecó (Brazil), indicated that the quantity of aluminum sulfate used for flocculating solids in suspension, fell with 46 percent over a period of five years. When water is chlorinated to kill disease organisms, the chlorine reacts with dissolved organic matter to form trihalomethane (THM) compounds such as chloroform. THMs are suspected to cause cancers (Fawcett, 1997). Reductions in runoff and erosion provided by conservation agriculture should indirectly reduce the formation of THMs during the chlorination process.

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.

According to Fawcett (1997) total herbicide use (kg ha⁻¹) in the USA declined during the period of adoption of no-tillage systems. He concludes that herbicides are important, but farmers using conventional tillage methods use similar amounts of herbicides as no-tillage farmers. In Honduras a strong decline in the use of herbicides is observed (figure 9). Farmers who no longer burn their fields prior to preparation spend less money on herbicides. Farmers who adopted the Quesungual system (conservation agriculture system with sparse trees) spend even less, both for land preparation and total costs for herbicides.
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.

One aspect of conventional agriculture is its ability to change the landscape. The destruction of the vegetal cover affects the plants, animals and microorganisms. 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 monocropping.

Systems, based on high crop residue addition and no tillage, tend to accumulate more carbon in the soil, compared to the loss into the atmosphere. 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 thus the liberation of carbon to the atmosphere also occurs slowly. In the total balance, a fixation or so-called sequestration of carbon takes place. This turns the soil into a net sink of carbon. The studies executed in south Brazil show indeed an increase in organic carbon in the soil (figure 10).

The fact that agriculture can act as a sink for CO₂ is shown in figure 11, in which the carbon stock in soils under natural vegetation is used as a reference (steady state ∆C=0). During 8 years, the fallow/maize system liberated 4.32 Mg CO₂ ha⁻¹. The maize/mucuna system showed a positive balance of almost 20 Mg CO₂ ha⁻¹ compared to fallow/maize (Amado et al., 2001).

Compared to soils under natural vegetation this means a capturing of atmospheric carbon of more than 15 Mg CO₂ ha⁻¹ in eight years. The figures presented confirm the potential of conservation agriculture for carbon sequestration, or at least reduction of the amount of carbon dioxide to the atmosphere.

Assuming an average accumulation of 1t C ha⁻¹ year⁻¹, an area like southern Brazil (Rio Grande do Sul, Santa Catarina and Paraná) under cultivation, applying the principles of conservation agriculture would have the potential to sequester 8 million tonnes of C annually, which corresponds with 29 million tonnes atmospheric carbon dioxide.
Limitations

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 agroecosystems are different. Especially information on locally adapted cover crops that produce high amounts of biomass under the given circumstances is often lacking. The success or failure of conservation agriculture highly depends on the flexibility and creativity of the practitioners and extension and research services of a region. Trial and error, both by official institutes as the farmers themselves, is often the only reliable source of information.

However, as conservation agriculture is gaining momentum rapidly, in a lot of regions already exist farmer organizations and groups of interested people who exchange information and experiences on cover crops, tools and equipment used in conservation agriculture.

Plate 7
Exchange of ideas and information on direct seeders in a Maasai community in Same District, Tanzania.
A.J. Bot
Adoption of conservation agriculture

In order to facilitate the change in production system towards conservation agriculture, it is important to understand why farmers think that soil tillage is such an important part of their system.

Soil is being tilled in order to break-up the soil after harvest of the previous crop, to eliminate weeds and to prepare the seedbed for the next crop. Farmers perceive it as being important and besides that they feel comfortable with the technology, they know how to manage the technology and they know that tillage activities render good crop yields.

To start with conservation agriculture requires:
- change in crop management system
- an implement or tool that can manage the crop residues or cover crops
- consider the soil as a biological and self-sustaining productive system
- adopt a new way of thinking as far as weed management and crop production are concerned
- improve the capacity to tackle new challenges and find a solution

How does a farmer start conservation agriculture?
- start with composure and concentrate on achievable objectives
- in order to gain experience, start on a small part of the farm
- initiate in an area where there is enough cover and use a tool or implement that can do the job easily
- in the case of using herbicides, take time to learn to identify and use herbicides in a correct way
- learn to identify and manage different problems
- talk to other farmers who are practising conservation agriculture and learn from their experiences and mistakes

Before starting with conservation agriculture one very important aspect is to plan a good crop rotation. As CA is based on soil life, soils have to be brought up to a condition where life can develop. Physical and chemical soil limitations, like compaction, drainage and pH, P and K should be corrected before changing towards CA. Especially in highly degraded or depleted soils this means some sort of melioration investment might be necessary to recover them, such as removing compactions, liming, use of green manure and synthetic fertilizer to correct extreme nutrient deficiencies. Soils under CA are usually improving, which means the rate of degradation and erosion is lower than the rate of soil build-up. For that reason even degraded soils will improve and might become productive under this system. A good example are the Brazilian Cerrados, which were considered degraded land unsuitable for farming and which have been converted by CA into a highly productive area.

The focus of conservation agriculture will shift, especially in the first years towards weed control and (cover) crop residue management, and monitoring pest and disease incidence. A farmer should be prepared for new habits and timetables.

Conservation agriculture is based on restoring natural occurring processes and therefore needs a conversion period before the new system is established and the natural balances are restored. It is good that starting farmers know others to share experiences and set realistic expectations. They as well need a period in order to gain experience with conservation agriculture.
Information sharing and exchange of experiences is necessary for farmers who are starting with conservation agriculture. Especially in the beginning a lot of information is needed on the use and adjustment of tools and implements. The specialized so-called "planter clinics" are very useful for farmers to learn not only about the tools and implements, but also on the time needed for conversion to the new system, crop yields during and after the conversion period, labour and time requirements in agricultural activities before and after the change. The experiences of farmers who are implementing conservation agriculture for a longer time might give indications to new ones which key practices generate success and what mistakes to avoid.

A number of environmental conditions might speed up the promotion of conservation agriculture. Generally the following conditions lead to a sub-optimal crop yield, farm income or environmental problems resulting from agricultural activities in these areas:

- hilly topography
- erosive rainfall
- arid climate, with very hot and dry periods
- soils that are loosing their productivity through erosion
- increased production costs
- diminishing labour capacity
- if applicable, diminishing agricultural subsidies

Under these conditions a change in system towards conservation agriculture might generate quickly momentum, as the results are clear, especially to farmers. Especially when opportunities like the presence of conservation agriculture organizations, farmer organizations and farmers who have experience with conservation agriculture are present in the region, conservation agriculture can lead to a quick change in social-economic circumstances of the people.

Innovative farmers who are looking for other production systems in order to save money, improve their techniques and their soils are probably the ones that will adopt CA first. They will also be the ones to promote CA in their communities.

One of the problems in promoting CA is the fear for changing "good" practices into new practices and the fact that these "good" or actual practices are culturally linked to the communities. The change will generate opposition within the community, which is completely normal, but it is useful to identify reasons and strategies for changing beforehand. Soil tillage is a traditional practice and thus presents some cultural barriers. Tillage is perceived as:

- necessary
- soil improvement
- facilitating crop management
- giving higher yields

Tillage is considered a tradition by farmers and changing the practice is difficult because:

- they are satisfied with the actual practices
- they know better than anyone else to manage their production
- they don't feel an economic pressure to change
- the attitude towards tillage defines a good farmer and this results in self-confidence

As extension officers and pioneer farmers will be the change agent in a region, they should assume a facilitating role that will encourage the confidence of starting farmers that the technology is working. This includes demonstrating the technology in other
farmers' fields, demonstrating the economic benefits with facts and numbers and train people in the region to help others.

<table>
<thead>
<tr>
<th>Box 1. Requirements of conservation agriculture as mentioned by farmers</th>
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<tr>
<td>Research has shown that the following agronomic and economic qualifications of conservation agriculture are important to farmers, and thus can provide the entry point for extension workers to discuss the advantages of CA:</td>
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<tr>
<td>- seedbed should be of same quality as in conventional tillage</td>
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<tr>
<td>- alternative for free-roaming livestock, as it compacts the soil through trampling</td>
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<tr>
<td>- increase of soil and crop productivity</td>
</tr>
<tr>
<td>- increase in organic matter of the soil</td>
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<tr>
<td>- capacity to control weeds</td>
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<tr>
<td>- capacity to reduce production costs</td>
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<tr>
<td>- same production level as CT</td>
</tr>
<tr>
<td>- accessible seeders - not too expensive</td>
</tr>
<tr>
<td>- time saving</td>
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As tillage is considered tradition some cultural barriers that might aggravate the change process can exist in a region. For extension personnel it is always important to recognize these barriers. They include:
- not understanding the technology
- being afraid of the economic risk
- not being able to buy equipment
- soils or crops are not adequate and need to be adjusted

Change does never appear "overnight" and will take time. Extension personnel therefore need to be patient and accept that agricultural technologies are adopted step-by-step, because farmers:
- need to feel at ease with the new technology
- do not have the capital to invest
- cannot run a big risk, especially not when the technology is not known
- need a learning-by-doing environment

All farmers learn and accept new things differently. To facilitate the work of rural research and extension activities, groups of farmers and their learning habits can be categorized. This is explained in detail in "Adoption of new technologies".

More information on converting conventional practices into conservation tillage can be obtained in the module "Conservation Agriculture in practice".
Adoption of new technologies

Adoption of an innovation is an individual decision-making process, and as such depends on personal characteristics of people. A social system or community can be split into so-called "adoption categories". Initially, this division is based on the time they need to adopt a new technology (figure). But a number of variables are closely linked to this time lapse, like education, income, farm size, leadership, membership of groups and organizations, attitude towards change, contact with extension services and attitude towards information gathering (Wapenaar et al., 1988).

![Adoption Curve](image)

**Figure .. "Adoption curve" (Rogers, cited by Wapenaar et al., 1988)**

In the beginning this curve was developed to indicate the process of adoption, based on the "trickle-down" effect. Experience has learned that adoption of new technology does not work this way and active participation of the farmers is needed.

Nowadays the curve is useful to identify the different groups within a community and be able to design more "client-oriented" extension material.

**Characteristics of adoption categories and their learning**

Innovators are:
- adventurers, they are not afraid to take risks
- usually well-informed and well educated
- interested in solving scientific problems
- conceptual thinkers
- community leaders
- highly visible or with a important social position

How do innovators learn:
- they like to observe and discuss new technologies and concepts
- they are constantly trying and looking for new ideas and information
- they like to be the first one and like the idea of being the pioneer
- they will try something when they are given some ideas about the benefits and reasoning
- they will find you, before you'll find them

Next group to adopt a technology is called "early adopters". They are:
- quick in fishing for promising ideas
- well educated
take part in meetings and workshops
highly involved in local activities and initiatives
known to be "good farmers"
have a humble attitude
aware of their influence and responsibility towards the community

How do "early adopters" learn? They:
- are not bound by tradition and can be easily convinced
- want to see facts and details about the technology
- are convinced easily when numbers are available
- observe the innovators to see whether they are successful
- like to implement research in their farms to learn about the new technology
- discuss among themselves in meetings and workshops
- read magazines and flyers on the topic

"Early majority" is:
- thoughtful and conservative in their actions
- observe the "early adopters"
- well rooted in the community and have a lot of contacts
- entrust on friendships and neighbours for information
- somewhat higher educated than the average
- has farms that are slightly bigger than average farms in the community

How do farmers in the "early majority" learn? They:
- are bound to tradition, but can be convinced
- want to see facts and details about the technology, for example in meetings and field days
- have a lot of confidence in the experiences of other farmers, already implementing
- like to discuss with friends and neighbours
- difficult to convince them quickly

The "late majority" usually is:
- bound to tradition
- less educated and less involved in the community
- highly dependent on others to obtain information
- smaller farms than the average
- fear risks and debts
- not following nor leading

How do farmers in the "late majority" learn? These farmers:
- are bound to tradition and are convinced slowly
- are highly dependent on experiences from other farmers
- need to see the technology in action a lot of times
- are not convinced until one of them has accepted the new technology
- need to learn about the new technology through mass media, like radio programmes

"Latecomers" or "late adopters" are:
- least progressive farmers
- bound to tradition
- change only when it is necessary
- fear risks and debt
- dependent on others to obtain information
- not followers
How do they learn? They:
- are bound to tradition and it is very difficult to convince them
- need to learn about the new technology through mass media, like radio programmes
- adopt a product or technology after it has demonstrated its use and usefulness and has been transformed into the "new" tradition

The traditional way of extension was based on visiting leaders in the community, with the idea that the rest in the community would take over the new technology. Often the new technology was treated as something that was really necessary for all and thus it was expected that the whole community would take over the new technology (top-down approach). This approach is not very effective and the adoption of innovations is slow. Each of the different groups need attention from the extension service, but in their own specialized way.

In order to obtain a successful adoption, it is necessary:
- to offer specific information for specific groups of farmers
- to allow farmers to progress in their own rhythm
- to entrust farmers to generate research data and other information

Therefore, it is important that farmers put forward research questions and possible solutions and that they initiate and implement the research themselves. The role of the extension service is reduced to a facilitating role and to provide additional information.
Frequently Asked Questions

**Does conservation agriculture cause compaction of the soil?**

It is possible that land under conservation agriculture is denser than land that has just been ploughed. However, with time and proper management (no heavy equipment on wet soils) soils under conservation agriculture will be less compacted than soils under conventional tillage.

**How are fields under conservation agriculture fertilized?**

Many farmers who are practising conservation agriculture use specialized planting equipment that also allows the placement of fertilizers next to the seeds. Others apply fertilizers by broadcasting them on the soil surface without any problems. The (cover) crop residues improve the soil moisture content, which makes nutrients in the topsoil more available for plants. This moisture stimulates the development of superficial roots, which absorb these nutrients and help to distribute them through the profile. The secret lies in not applying too much fertilizer and keeping a close eye on how fertilizers behave under conservation agriculture, especially during the first years.

**Is it true that I have to wait for four to five years until my crop yield is at the same level as under conventional tillage?**

Crop yields under conservation agriculture are comparable or higher compared to those obtained under conventional tillage. If a soil has been tilled for a long time, the changes in the soil resulting from the new conservation agriculture system might be slow at the beginning. Experiences have shown that, depending on the type of soil and management, after a period of four to five years crop yields can be higher than under the conventional system.

**Why do my crops turn yellowish and show retarded growth after germination?**

If there are a lot of residues accumulated on the soil surface, it is possible that some of the nitrogen in the soil is immobilized by microorganisms in the decomposition process. Especially during the first years an application of nitrogen (either chemical fertilizers or manure) before sowing might alleviate this problem. Also the incorporation of legumes might help.

**I was told that under conservation agriculture I will have more pests and diseases.**

It is a myth that there are more pests and diseases under conservation agriculture conditions. The residue cover provides a habitat for a more diverse species composition, in which natural enemies of pests and disease causing organisms have a better change of survival. Conservation agriculture foresees in a more balanced ecosystem. It is true that some (formerly known as pest insect) organisms dwell better in the residue cover, but they usually resume a beneficial role in the ecosystem. In order to minimize situations of pest and disease development, a proper crop rotation, including resistant varieties should be implemented.

**Crop germination is worse and irregular under CA?**

Under extreme conditions (dry soils or cold spells and wet conditions) crop emergence will be low both under conventional tillage and conservation agriculture. An adequate sowing depth in which the seed is in close contact with soil particles is always important.

**Is it possible that weeds resistant to herbicides develop, when using herbicides to prepare the land?**
If appropriate doses are used the chance of developing resistant weeds is remote. With time less weeds will appear in the field and thus the use of herbicides will be reduced as well.

If not tilled, would the soil not be compacted and water infiltration reduced? Exactly the opposite will occur. When practising conservation agriculture, the soil will turn looser than under conventional conditions. This is because soil life will take over the mixing and loosening activity that used to be done by ploughs. The soil will have more organic matter, higher porosity and more large aggregates and thus the infiltration capacity of the soil will increase.

What is the first step to be taken, when one wants to start practising CA? Obtaining information on appropriate cover crops in the region from any source, like family and friends, extension services, research stations and, if applicable the Internet would be the first step to be taken. Start on a small area that doesn't have a lot of limitations and acquire little by little experience on how to manage the new system under your own farming conditions.

I have a soil with low organic matter content, that is not very productive and I do not get high yields. What do I have do to get more organic matter? First of all activities in the field need to be aimed at increasing biomass production and accumulation. This means that after crop harvest, the residues are conserved on the soil and left to protect the soil and act as food for the soil organisms. During off-season a cover crop should be grown that can still produce biomass with the water stored in the profile or at the temperatures present. Burning and grazing of residues must be avoided as much as possible.

Why should I change to CA if the system I am using now works well? Conservation agriculture improves the efficiency and the productivity, because:

- it reduces the number of field operations and allows the farmer to plant and manage a bigger area
- earlier planting/seeding becomes possible when the soil is no longer ploughed
- it reduces long term investments
- it reduces labour and thus allows the farmer to dedicate his/her time to other activities

If I would practice CA, would I be using more agrochemicals? And what would this do to the environment? Experience shows that it is not necessary to use more agrochemicals under conservation agriculture compared to the conventional situation. Many people think that herbicides are essential for CA, but alternatives have been developed through the use of cover crops and mechanical management of weeds and cover crops. In situations in which herbicides are used during the first few years of changing the system, herbicide use drops below the level of conventional tillage systems after a few years. Fertilizer use can be reduced over time as the efficiency of fertilizers increases through the increased organic matter content of the soil.

Will it be cheaper to use chemicals than till the land? If all production costs are included in the calculation, like labour, machinery and equipment, write-down, saving of soil moisture, etc. it is clear that 1 or 2 litres of herbicide costs less to cultivate one hectare.

Conservation agriculture only works in certain climates or on certain soils.
Conservation Agriculture is practised in many agroecological zones, from the humid tropics to almost the Arctic Circle and on all kinds of soils. So far the only areas where the concept has not been successfully adapted are arid areas with extreme water shortage and low production of biomass. In these areas both humans and animals compete with the soil for crop residues.

**CA only works for grain crops.**
The system has been adapted for vegetables and root crops. Now, not only grain crops and pulses but also a wide range of other crops such as sugar cane, vegetables, potatoes, beets and cassava, can be grown. Perennial crops like fruit and vine can also be grown using CA techniques.

**Conservation agriculture is only for large mechanized farms.**
The majority of conservation agriculture farmers are smallholders who trust on family labour and animal traction. Technologies and equipment have been developed and adjusted by these farmers to practice conservation agriculture on small farms with animal traction and on very small farms with only manual equipment.
References


