SOIL CULTIVATION AND CONSERVATION AGRICULTURE

Soil cultivation

Soil is cultivated to combat weed, pests and diseases, to incorporate crop residues, and chemicals and to create a favourable seedbed for seedling emergence and growth. Soil is sometimes cultivated to control wind erosion.

Mouldboard and disc ploughs are used to achieve one or more of the mentioned objectives in conventional cultivation systems. The soil is pulverised and inverted and crop residues are mixed with the soil in the plough layer through the ploughing action. The soil surface is usually left with little, if any residue. Secondary shallower tillage actions are often done with tine or disc implements to achieve one or more of the mentioned objectives.

Conventional cultivation systems have however, some important disadvantages. Due to the disturbance of the soil, its quality deteriorates as reflected by the decline in the organic carbon content. The soil structure is also destroyed or deteriorates, the erosion susceptibility increases and the life cycle of some micro-organisms is disrupted. In many instances water runoff and the consequent erosion are enhanced by soil cultivation. Soil cultivation and its fuel and mechanization requirement is a major portion of the costs associated with crop production.

On many soil texture classes, conventional ploughing usually results in compaction in the sub-soil which limits root growth. Sandier and wetter soils usually compact faster under plough and disc cultivation actions than drier and more clayey soils. In such cases, deeper and more costly tillage methods are usually required which results in further deterioration of the soil quality. Clay soils that shrink and swell under drying and wetting spells usually can alleviate compaction naturally.

Deterioration of soils, resulting erosion and ever increasing energy and mechanisation costs have resulted in an awareness that alternative cultivation practices are required. As a result, reduced and conservation tillage practices, where only tine implements are used, were introduced some decades ago with the inception of herbicides. Tillage actions, previously primarily aimed at weed control, were replaced by herbicide application resulting in reduced tillage.

The objective with conservation tillage is to leave at least 30% of the soil surface covered with crop residues after cultivation whereby erosion is restricted and the initially high water infiltration rate is prolonged. Chisel plough cultivation usually succeeds in these objectives, provided that the initial amount of crop residue was sufficient. The well-known rip on row cultivation that is practiced, especially on the sandy soils of the Free State, can also be con-
Considered as conservation tillage since most of the residue is left on the soil surface. However, chisel plough, rip and other comparable tillage actions, disturb the soil enough to undermine its quality.

The best indicator of soil quality is its organic carbon content and a higher content indicates a higher quality. During the past 70 to 100 years the organic carbon content of soils on the Highveld declined by as much as 75% due to conventional tillage methods. The organic carbon content plays an important role in the physical and chemical characteristics of soils. A higher organic carbon content is associated with a higher cation exchange capacity and water retention capacity as well as a lower susceptibility for compaction and surface crusting.

Sustainable future crop production is non-negotiable. Soil quality deterioration should be prevented and everything must be done to rather improve it. Soil quality (also known as soil health) is the sum total of the chemical, physical and biological ability of a soil to sustain crop productivity at a high level. At the same time, erosion must be prevented. These objectives can only be achieved through conservation agriculture.

**Conservation agriculture**

The objective of conservation agriculture is to maximise soil quality and to minimise soil erosion and the impact on the environment. Through improvement of soil quality, the utilisation of natural resources such as rainfall and soil are also maximised. Soil of a high quality has no chemical or physical limitations. The microbial population will be as high or diverse as allowed by the climate.

Conservation agriculture consists of the application of certain crop production principles namely:

1. Minimum soil disturbance.
2. The creation and maintenance of a semi- or permanent mulch of plant residue.
3. Crop rotation.
4. Controlled traffic on compact prone soils.

**1. Minimum soil disturbance**

In conservation agriculture a primary soil cultivation is not done any more and the only “cultivation” that really occurs is the planting action. An important condition is that the disturbed area must be less than 15 cm wide or less than 25% of the cropped area (whichever is lower). The ideal scenario is no-till where the soil is only disturbed within the plant furrow.

Limited experience currently indicates that sandier soils need deeper disturbance than clayey soils at planting to ensure crop establishment and deep placement of fertiliser. Guidelines on
the allowable depth of disturbance, in relation to texture class, are not yet available. Disturbance depths of 150–250 mm appear to be adequate on some sandy soils in the Free State and Northwest.

An important beneficial consequence of minimum soil disturbance is that the destruction and consequential decline of the organic carbon content ceases and that it can recover. The erosion susceptibility also decreases and micro-organisms within the soil are not disturbed or destroyed. Minimum disturbed soil is usually dominated by fungi, which is a more stable source and storage environment of plant nutrients rather than bacteria. Fungi also play an important role in the formation and stabilisation of the soil structure and can suppress parasitic nematodes. Minimum soil disturbance is therefore necessary to reverse the quality decline associated with tillage.

2. Permanent or semi-permanent soil cover

Conservation agriculture requires that at least 30% of the soil surface should be covered with plant residue (previous crop and weeds) directly after planting. Plant residues protect the soil against erosion and in many instances can have a favourable effect on water infiltration rate from rain or irrigation. Water run-off and the associated environmental impact are consequently reduced. The cover also serves as a slowly released source of food for soil organisms.

In most cases, crop residues are utilised as animal feed and to leave it intact on the soil is not in line with the custom on most farms. Limited usage of residue is possible, but the advantages and disadvantages thereof must be considered. Results from America have indicated that maize yields increase by 34 kg ha\(^{-1}\) for every percentage increase
Soil cover is measured with a tape measure or line with pre-marked points diagonally laid over the planting direction and determining if there are bare soil or plant material under these points. The percentage of points which have plant materials, represent the cover and it should preferably be more than 30% to qualify for conservation agriculture.

In soil cover. If animals are allowed to graze these residues it is important that the required 30% cover still be maintained.

Residues should be left intact after harvesting until the next planting action. In contrast with fields where residues were shredded and flattened with a knife roller (or “rolmoer”), standing maize stems are better in preventing wind erosion, are not washed or blown away and decompose slower, resulting in a mulch that remains intact much longer. An even spread of residues on the land by combine harvesters is important for its effectiveness.

### 3. Crop rotation

In the ideal crop rotation system, at least three different crops should follow each other, for example, forage sorghum – legume – maize. Soil microbe activity and diversity usually thrive in such systems especially when a legume crop is included. The increased activity and diversity limit the ability of pests and pathogens, such as nematodes, to harm the crop and as a result increases the soil quality. Grain yield and grain quality are usually higher in crop rotations where the crops are diverse.

Due to economic and other considerations, it usually is not viable to produce three different crops in a 1:1:1 area ratio. Although not ideal, workable alternatives are to use ratios of alternative crops to maize area of 1:1 to 1:4.
Minimum soil disturbance entails that the disturbed soil should be less than 15 cm wide or less than 25% of the cropped area (whichever is lower) as measured directly after planting.

4. Controlled traffic

Since tractors and implements are the main source of soil compaction, controlled traffic is recommended on compaction prone soils. Higher clay content and drier soils are less prone to compaction. Tractors and implements which are unnecessarily loaded with weight than for the task it is used for, should be avoided. An increased contact area between tyres and the soil will also reduce the probability for compaction. Wider and larger tyres which are not inflated too high are better than small highly inflated tyres.

Requirements and bottlenecks of conservation agriculture

Worldwide experience has shown that the attitude of farmers is critical for the successful application of conservation agriculture.

Before a land is converted to conservation agriculture, all existing soil compactions and acidity must be alleviated through tillage and liming. The chemical and physical components must therefore first be corrected before the microbial component of minimum disturbance and crop rotation can flourish.

Conservation agriculture requires effective planters and herbicide spray-
The effect of crop rotation with a legume on the growth and production of maize, can be dramatic in some seasons. The maize on the left was mono-cultured, while that on the right was preceded by a legume crop.

ers that usually result in capital expenditure. Huge savings however, are obtained on time, labour, fuel and maintenance of machinery. The total capital investment in tractors and equipment is lower than those of conventional practices and crop production systems.

Weed control in conservation agriculture requires knowledge of weeds and herbicides as well as the entire control process. Ineffective weed control is an important cause of failed attempts to convert to conservation agriculture. The weed spectrum usually changes when changing to conservation agriculture and expenditure on herbicides usually increases. Without the inclusion of a glyphosate tolerant crop in the rotation system, the conversion to a conservation agriculture system will probably be very difficult.

With the change to conservation agriculture, growth conditions for pests and diseases changes. Some might be enhanced while some might be suppressed. Good observation and management of insects, diseases and pests such as rodents is therefore required for timeous action.

Initially, maize grain yields can be below that of conventionally produced crops after changing to conservation agriculture. It is therefore recommended that the first crop to be planted in undis-
turbed soil rather be a legume that can boost the follow-up maize crop. Crop responses to conservation agriculture are related to soil and environmental conditions, which often requires patience.

Animals on conservation agriculture lands can cause soil compaction and destruction of the mulch. One view is that animals should not be allowed onto conservation agricultural lands. A second view is that animals be allowed on such lands as long as the soil is dry and the 30% soil cover threshold is maintained.

Initially, nitrogen fertilisation rates should be increased with about 10–15%. Soil acidity, as depicted by the acid saturation, should be strictly managed. Lime and gypsum cannot be administered as a correction measure such as with conventional systems, but should be applied regularly in smaller quantities to prevent the development of excess acidity.

Concluding remarks

Conservation agriculture is seen by many farmers as a cost reducing practice rather than a resource and environmental conservation action with the advantage of optimal resource utilization. It does not necessarily cut costs, since savings on fuel and mechanization is usually balanced out by increased reliance on herbicides and other chemicals. In due time, yields of crops in conservation systems can exceed those of crops in conventional tillage systems. Weed pressure also decreases with time, resulting in a decrease in herbicide application rates and improved economics.

Local soil and climatic conditions determine the finer details of conservation agriculture but there is no single recipe for success. Only through trials conducted under local conditions can the refined requirements for minimum soil disturbance, crop rotation system to follow, how often lime should be applied etc., be established.