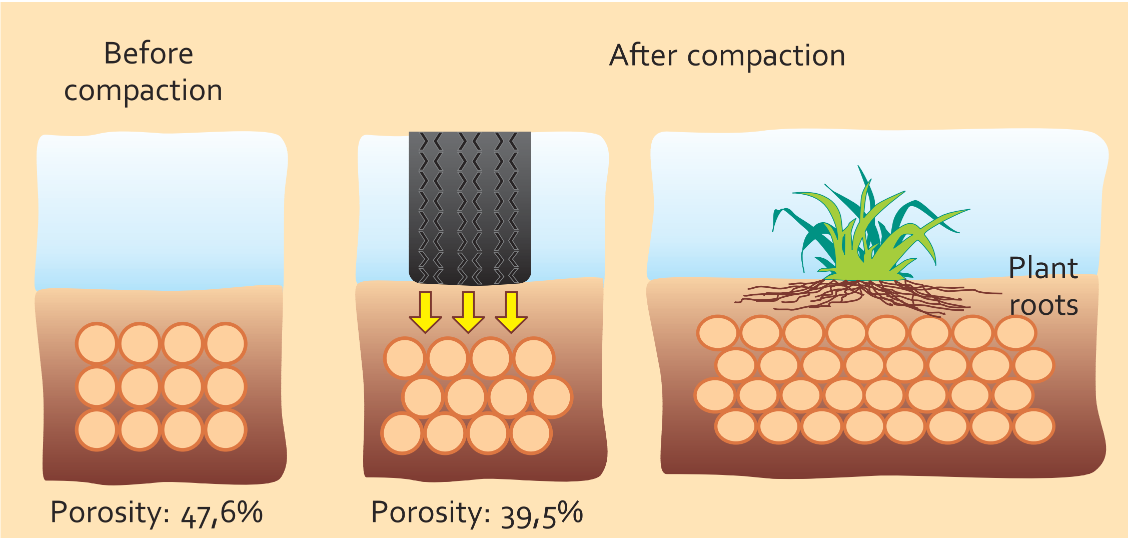
Information Sheet

6.10 Compaction

*With the ever-increasing use of heavy equipment, compaction has become an important crop-limiting factor for sugarcane production in South Africa. Infield haulage vehicles and, to a lesser extent, tillage implements, re-orientate and compress soils so that pores are reduced in size and number. This leads to **increased bulk density**. Soil structure becomes rigid and dense, and particles are moved with great difficulty to accommodate root growth. This also limits air and water movement into and through the soil.*



▲ Figure 1: Compaction reduces soil porosity and increases bulk density, restricting water and airflow and constraining root growth.

Effects of compaction

Infield traffic not only increases soil bulk density but also damages stools when the wheels drive over cane rows. Due to compaction, the soil will store less water leading to more frequent periods of water stress and therefore yield loss.

Other effects of soil compaction include:

- reduced water infiltration rate leading to a low water use efficiency,
- reduced pore sizes causing oxygen and carbon dioxide exchange to be slower,
- increased surface run-off potential and erosion hazard,
- increased waterlogging and loss of nitrogen through denitrification.

The effects of soil compaction will lead to a decline in sugarcane yield. The extent of this loss will depend on numerous factors, such as soil type, depth and degree of compaction. For instance, it is reported that an increase in soil density of a sandy clay loam (clay content between 20 and 35%) from 1.30 to 1.55 g/cm^3 will reduce the mass of millable sugarcane stalks by up to 22%.

How to detect compaction

The presence of a compacted layer may be revealed by:

- prolonged ponding on a surface after rain or irrigation (often observed in wheel tracks).
- pushing a thin rod (5 mm diameter) with a sharp point vertically into the soil to detect the depth of a dense soil layer (layer at which there is a marked increase in the resistance to penetration).
- digging a soil pit and examining root behaviour. Compaction will deform the roots, and cause them to thicken and bend as they try to enter the dense soil layer.

Other indicators of compaction are:

- a crusted soil surface (soils with a grey topsoil is vulnerable to crusting and compaction).
- signs of water running on the surface.
- a lack of deep, finely branched roots or earthworm holes.
- the presence of platy structure (2 to 5 mm thin horizontal layers of dense soil).
- poor drainage and mottling caused by impeded drainage.

Types of compaction

Compaction can be classed according to the type and cause of the compaction:

Traffic hardpans

In sugarcane, this type of compaction occurs near the surface and is caused by wheels of equipment used. These are more common in sandy soils (less than 35% clay) and tend to be greater when the soil is moist to wet. They affect the area from the soil surface to several centimetres below, depending on weight of the equipment (Figure 1).

Figure 2. Surface crusts.

Plough pans

Plough pans are caused by tillage equipment working the soil in preparation for planting and occur just below ploughing depth. Depending on the size of equipment, depth of ploughing and properties of the soil, compaction can occur at different depths in the subsoil. Subsoil compaction increases soil density, and roots will penetrate the layer at a slower rate causing them to become thick and not well-branched. Roots can also grow horizontally along the top of the compacted layer. Due to infrequent ploughing because sugarcane ratoons after harvest, this form of compaction occurs less frequently than traffic hardpans.

Surface crusts

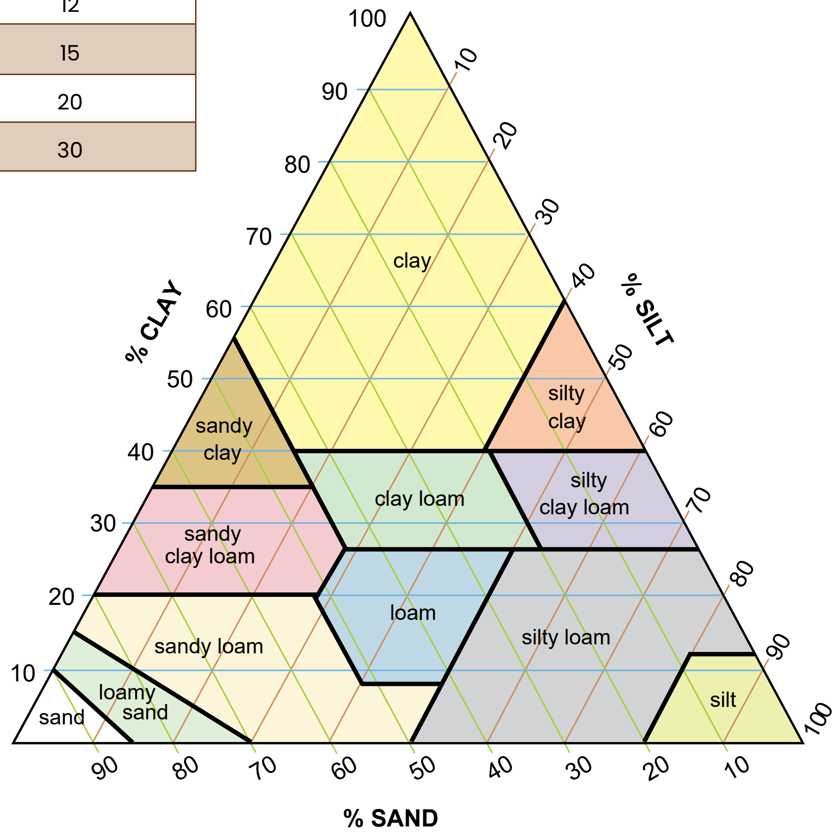
Surface compaction or crusting is a special type of compaction at the soil surface. It is mainly caused by water droplets from rain or irrigation. The crust is usually thin (< 2 mm) with signs of runoff nearby. In some sandy loam to clay loam soils (between 20 to 40% clay with up to 50% silt) with very poor structure, the crust can be up to 10 mm thick, offering extreme resistance to the germinating crop. Crusts are recognised by the "sealed" surface appearance (Figure 2). In extreme cases, signs of erosion will also be visible. Regular alleviation is recommended before germination, through the use of a rolling cultivator, spring tine hoe or other shallow cultivating equipment (Figure 5). Mulching is very effective to reduce the incidence of crust formation.

Factors affecting susceptibility of soils to compaction

The two main soil properties that affect the level of compaction are soil water content and clay content (Figure 3). In most soils, compaction caused by traffic is greatest when the **soil water content** is near field capacity.

Table 1: Soil types and the water content (%) at which soil is susceptible to maximum compaction.

Soil type	Water content (%)
loamy sand (< 15% clay)	12
sandy loam (< 20% clay)	15
loam (8 to 25% clay)	20
loam (8 to 25% clay)	30



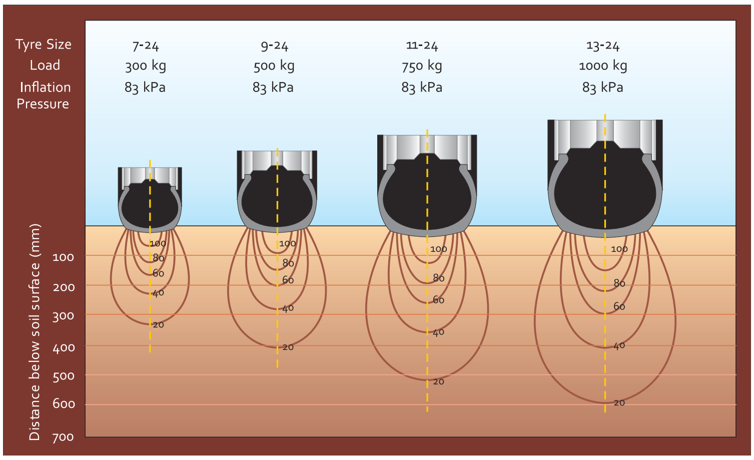
▲ Figure 3. Soil water content and clay are the two main soil properties that affect the susceptibility of a soil to compaction, especially from in-field traffic.

Soil pressure caused by agricultural equipment is determined almost exclusively by the characteristics of the equipment and the operations performed. A general rule is that the average pressure exerted between pneumatic tyres and the ground is equal to inflation pressure of the tyre. Exceptions to the rule are:

- Tyres with stiff side walls transmit the loading force directly to the ground.
- Pressure under the lugs (raised portion of the tread) of tyres with stiff side walls is higher than the inflation pressure.

Pressure distribution patterns under various tractor tyres are shown in Figure 4. Notice the increasing depth of compaction with increasing load.

Figure 4. Higher vehicle loads lead to a greater depth of soil impacted by compaction. ▶



The reduction in soil porosity and infiltration rate is greatest after the first pass (about 60 -70%). Each additional pass over the same path will be less damaging but will further increase the density of the soil. Slow moving equipment applies pressure for longer periods; the higher the speed of the equipment, the less the reduction in porosity that will occur.

Ameliorating compaction

Shallow and near surface compaction and crusts can be broken up using shallow cultivation equipment that will disrupt and crack open compacted layers (Figure 5). This is normally done under dry conditions.

▲ Figure 5. Rolling cultivator (left) and dragging cultivator (centre and right).

Shallow compaction up to a depth of 100 mm is caused by tyres of equipment and alleviation does not require much energy (Figure 6). A chisel plough will adequately alleviate this compacted layer.

▲ Figure 6: Shallow compacted layer in a sandy soil exposed by erosion. Chisel plough on the right.

Compaction deeper than 200 mm is mainly caused by soil preparation implements such as the disk plough and mould board plough of different designs. This compacted layer is highly detrimental as it slows down the rate of water infiltration and gives rise to water logging, run-off and erosion. After rain, water is sometimes ponded on the surface for days, indicating that infiltration and drainage are not sufficient. In addition, the roots are confined to the plough layer (Figure 5), which usually results in reduced yields. Sub-soilers are required to rip the soil to a depth of at least 500 mm to alleviate the confounding layer (Figure 7).

◀ Figure 7: Plough pan (Left) and subsoiler (Right).

Restoring compacted soils

To rectify problems, the type of compaction must be identified. **The aim should be not to perform any tillage operation deeper than the required depth.**

The best time to alleviate compaction is during the fallow period. If it is considered during the cropping cycle, then the best time will be the first week after harvesting. Outside this period, there is a high risk of damaging the roots of the germinating crop, leading to yield losses. Important reasons for alleviating compaction are to increase soil water intake rate and reduce run-off and erosion. Other considerations:

- Rip compacted soils when dry for the shattering action of the subsoiler to be more effective. To avoid natural re-compaction, incorporate filtercake, bagasse or other sources of organic matter to a depth of 400 mm using a vertical mulcher. Otherwise, plough it into the surface layer.
- Green manuring will rejuvenate compacted soils and increase yield of at least the plant crop. See SASRI Green Manure Manual for options.

Avoiding or minimising soil compaction and cane stool damage

It is more cost effective and sustainable to avoid unnecessary compaction than to ameliorate compacted soils. Consider the following:

- Retain sugarcane residue after harvest to create a mulch. Where cane is burnt, practise cool burns in the early parts of the morning.
- Fields that are susceptible to crusting should be covered with a mulch blanket and be green manured during the fallow periods.
- Harvest fields most prone to compaction during the dry season, using the soil information given in Table 2.
- Do not drive over your cane stools - the damage is permanent yield loss!
- Consider controlled traffic to confine traffic to the interrow. Use the same interrows for traveling repeatedly to minimise the compacted area. Consult your Extension Specialist to design a controlled traffic system for you.
- Limit the total load and equipment mass to a minimum. Large capacity trailers should be equipped with walking beam axles, high flotation tyres and should be kept off the cane row.
- Keep tyre inflation pressures as low as feasible and use radial rather than cross-ply tyres.
- Use weight transfer hitches on trailers to equalise the load on all axles, and to limit wheel slip.
- Ideally tillage operations should be conducted when conditions are optimal per soil type (see Table 3).
- Train your loader operators not to damage stools when loading cane and not to spin wheels in the field.
- When loading mechanically, place as many rows as possible into one windrow to reduce the amount of traffic per unit area.
- On susceptible soils, avoid a loading and haulage system that may result in increased cane stool damage (e.g. a shuttle system).

Suggested harvest programme based on soil groups

Soil description	Soil form	Suggested harvest season
Valley bottom soils	Estcourt Katspruit Bonheim Rensburg	Winter
Grey sandy loams	Longlands Kroonstad Westleigh Glenrosa	Winter/spring
Clay and clay loams	Arcadia Tambankulu Milkwood Swartland Shortlands Hutton (Makatini)	Spring/summer
Brown humics	Inanda Kranskop Nomanci Magwa	Summer
Recent sands and alluvial soils	Fernwood Dundee Hutton (Clansthal)	Summer

Timing and ease of soil tilth preparation for soil groups

Soil description	Soil form	Consistency	Ability to obtain good tilth	Recommended time to prepare tilth
Grey sands, Loamy sands	Fernwood Dundee Cartref	Soft when wet, friable when dry	Easy	Any time
Brown humics	Inanda Kranskop Nomanci Magwa	Soft when wet, friable when dry	Easy	Any time
Red loams	Hutton (Clansthal) (Shorrocks)	Soft when wet, friable when dry	Easy	Any time
Grey sandy loams	Longlands Kroonstad Glenrosa Westleigh Estcourt	Soft to slightly plastic when wet, cemented when dry	Moderate	First spring rain
Red clay loams, Clay	Shortlands Hutton (Makatini)	Plastic when wet, cloddy when dry	Moderate	Spring
Black clays	Arcadia Bonheim Milkwood Rensburg	Very plastic and slippery when wet, hard and cloddy when dry	Difficult	Winter, early spring

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