Soil Compaction

Problems and Solutions

Department of Agronomy

Soil compaction can be a problem on most Kansas soils. Compaction can reduce plant growth, reduce root penetration, restrict water and air movement in the soil, result in nutrient stresses, and cause slow seedling emergence. Ultimately, compaction can reduce yields.

Soil compaction has become more of a problem in recent years due to increased equipment size and lack of crop rotations. In continuous mono-cropping, more tillage passes may be needed to control weeds and bury crop residue that could foster diseases. Increased vehicle traffic increases the potential for compaction.

Increase in field size can contribute to compaction, too. Larger fields may contain more variation in soil conditions. When working a large field, some sections might be dry while others are still too wet. When fields are smaller, each field is in more uniform condition and tilled only when ready.

Soil properties and compaction potential

To understand compaction, one must first understand the makeup of the soil. Soil consists of organic matter, minerals, and pore space. The mineral fraction of the soil is made up of a combination of sand, silt, and clay particles. These particles do not fit together tightly, but are surrounded by open pore spaces. This open space is important because it allows soil to hold air and water. Spaces between the particles are filled with air in dry soil, water in saturated soil, or both in moist soil. Soil compaction occurs when soil particles are pressed together, limiting the space for air and water.

The amount of soil water is a critical factor in soil compaction potential. A dry soil, which has friction between the soil particles, is not easily compacted. Water acts as a lubricant between the particles, making the soil easier to compact.

However, as soil water content increases, a point is reached where most pore spaces in the soil are filled with water, not air. Water cannot be compressed, so water between the soil particles carries some of the load of the soil, resisting compaction. Therefore, a very wet soil will not compact as much as a moderately moist soil.

Figure 1 demonstrates the relationship between soil-water content and susceptibility to compaction. The vertical axis shows the susceptibility to compaction. The horizontal axis shows water content. The gray zone shows where most soil compaction occurs. To the left of the gray zone, less compaction occurs; to the right, soil gets squeezed to the side rather than compacted. Avoid traffic on wet soil, traction is difficult and can leave ruts that have to be tilled out later.

Soil texture (the percentage of sand, silt, and clay in a soil) has some effect on compaction, although compaction can be a problem to one degree or

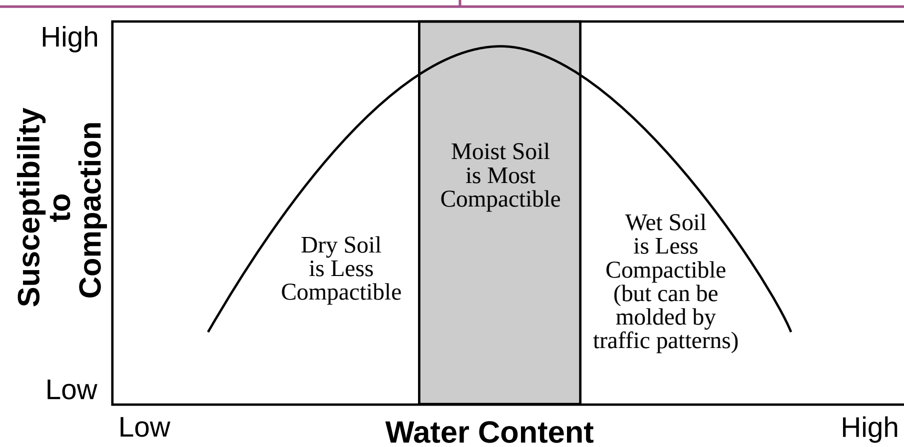


Figure 1.

another in almost all soil types. Soils made up of particles of about the same size compact less than soil with a variety of particle sizes. Smaller particles can fill the pores between larger particles making for a more dense soil. A sandy loam soil (67 percent sand, 24 percent silt, and 9 percent clay) is the most susceptible to compaction. Soil texture is not easily changed.

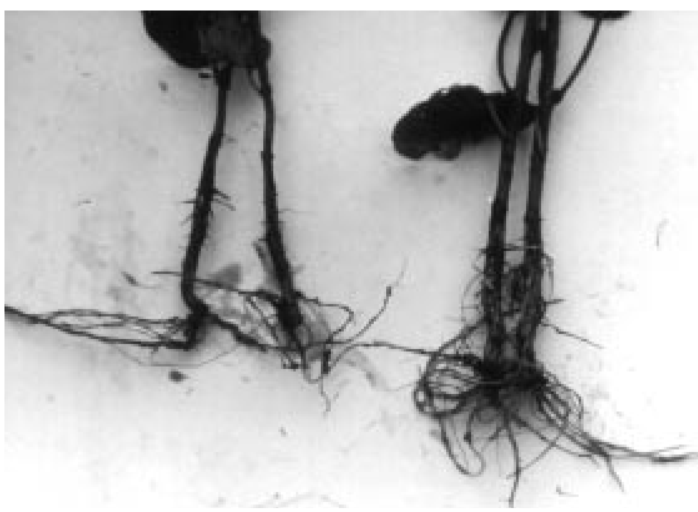
The structure of a soil (how well the soil breaks up into small, cohesive clumps when crumbled) also plays a role in its potential for compaction. A soil with higher levels of organic matter generally has better structure and resists compaction better than soils with lower organic matter levels. Organic matter helps create larger and stronger soil aggregates. Hard, dense, low organic-matter soils suffer more from compaction than loose, friable, high-organic-matter soils.

Types of compaction

Naturally dense soils — Most dense soils have a high clay content in some parts of the soil profile. Soils that are dense by nature cannot be easily "un-compacted." Enormous amounts of sand and silt would be needed to do so. Attempts to mix sand and clay layers in river bottom soils and sea shore soils have had varying degrees of success. Tillage offers only a short-lived solution in these soils. Prevention of additional compaction is the best management strategy in naturally dense soils.

Surface crusting — Some soils are sensitive to surface crusting caused by rainfall impact. In years with excessive or high intensity rainfall, the soil tends to be "hard." Crop residue or vegetative cover is the best means to prevent surface crusting and soil sealing in all soils. Soils without residue cover form a dry surface crust that is difficult for emerging seedlings to penetrate.

Tillage pan — Tillage implements that shear the soil, such as moldboard plows, disks, and sweep-type tools, have a tendency to cause soil compaction. When continuously operated at the same depth, tillage implements orient soil particles in the same direction, creating a layer of compacted soil. This compaction is typically referred to as a tillage or plow pan. The potential to cause a tillage pan is greater under wet soil conditions than under dry conditions.



Malformed roots (left) indicate a compaction problem.

It is difficult for roots and water to penetrate a tillage pan. A tillage pan effectively reduces the rooting depth to the depth of tillage, which is usually only 5 to 8 inches.

The photo below shows roots that tried to penetrate a tillage pan. By limiting root depth, the tillage pan makes plants susceptible to drought, excessive moisture, and nutrient shortage.

Vehicle-induced compaction — This form of compaction can be divided into two types—shallow and deep.

Shallow compaction is defined as any compaction occurring within the normal tillage zone. For some producers this may be 5 inches deep and for others it may be 10 inches deep. Shallow compaction is related to the pressure applied to the surface of the soil.

Higher ground pressures cause more shallow compaction. However, shallow compaction is usually temporary since it can be eliminated by normal tillage.

Deep compaction is defined as compaction that occurs below the normal tillage zone. It is caused by weight or force applied to the soil, and is mostly affected by the maximum axle weight.

Compaction from cultural practices — Excessive tillage tends to break down soil aggregates, resulting in poor soil structure and higher potential for compaction. Tillage hastens breakdown of the organic matter that is needed for good soil structure. Crop sequences, residue production, and residue management can all affect soil structure and compaction potential. Practices that leave surface residue undisturbed help increase or maintain a good organic matter level, which favors good soil structure and reduces the potential for compaction.

Symptoms of soil compaction

Soil compaction has many symptoms. The effects of compaction are often unnoticeable in the field, but a closer look may reveal problems. Signs of compaction may include:

■ Visible wheel-track patterns in a growing crop.

■ Malformed plant roots. Roots encountering a compacted zone may be enlarged and stubby, twisted or thin and flattened. Also, shallow root systems growing horizontally rather than vertically indicate a compacted soil (see photo).

■ Standing water or excessive water erosion. Standing water could be the result of a compacted layer restricting water infiltration or surface crusting caused by lack of crop residue and low organic matter. Poor infiltration due to compaction can also cause increased runoff and erosion.

■ Increased power requirements for field operation. Compaction increases soil strength and can make it harder to pull tillage implements.

■ Stunted plant growth. Stunted or nutrient-stressed plants could be suffering from compaction. If compaction is limiting root growth, plant water and nutrient uptake can be severely affected. This often shows up as discolored leaves and premature drought stress.

■ Reduced yields. The ultimate symptom of compaction may be reduced yields. Research in Indiana on a silt loam soil showed a 110-bushel corn yield reduction on a severely compacted soil compared to an uncompacted soil. Four years later, the compacted soil was still producing 25 bushels less corn than uncompacted soil.

Detecting soil compaction

If compaction is suspected, the best tool to find it is a shovel. Surface crusting and tillage pans can easily be found with a shovel. Vehicle-induced compaction is harder to find, however. This kind of compaction occurs over large areas and is difficult to isolate. To test for vehicle-induced compaction, start by digging first into a wheel track, then into an adjacent area. Any differences in hardness may indicate compaction, but it could also simply be a difference in soil density. It may be best to make the comparison dig from a section of the field where no traffic has occurred.

Cone penetrometers are often used to locate compaction. However, they are difficult to use. Motor-driven penetrometers, which penetrate the soil at a fixed speed, measure penetration resistance accurately. Since penetration resistance is a function of soil density and moisture content, not necessarily compaction, penetrometers need to be used in combination with soil moisture samples to the depth of penetration.

Preventing soil compaction

The best cure for compaction is to avoid it. Elimination of all compaction may be impossible, but there are several management factors that can keep compaction to a minimum.

The best management decision to prevent compaction is to not work soils that are too wet. Check for wetness at the depth of tillage operation, not at the soil surface. If the soil can be pressed into a ball that holds its shape, it is too wet.

Tillage implement selection can be important in reducing the formation of tillage pans. Moldboard plows and disks are known to cause tillage pans. The shearing action of these implements has a tendency to smear the soil and seal it. They bury more residue than shank-type tillage tools. Other implements that shear soil and cause tillage pans are tools equipped with large, rigid sweeps. Operating these tools at the same depth for a few years without varying tillage passes will cause a compacted layer in the soil.

Shallow compaction can be reduced by decreasing ground pressure, which can be accomplished by choosing larger tires, adding tires (using dual tires instead of singles, or triples instead of duals), or choosing a tracked vehicle. By adding duals or using a larger tire, more area is compacted due to the wider track but the intensity of the pressure is less. Operating at the proper tire inflation pressure is important in minimizing shallow compaction as inflation pressure is approximately equal to ground pressure.

Radial tires have a larger footprint that should reduce shallow compaction. An attractive feature of radial tires is that the footprint is longer and not wider than the same size bias tire. In this way, a radial tire achieves a larger footprint without compacting a wider track as it passes over the field. Radial tires also have greater load-carrying capacities than equal size bias tires and can be operated at lower inflation pressures, which will result in less shallow compaction.

Deep compaction can be minimized by reducing axle loads. This means operating at lighter weights for two-wheel drive tractors or possibly choosing a similarly powered mechanical front wheel drive or four-wheel drive tractor. Axle weight is not reduced by distributing the weight between more tires on the same axle or using tires with larger footprints. Also, carry only enough ballast on the tractor to pull the desired implements efficiently.

Recent research shows that reducing ground pressure to a minimal value (less than 12 pounds per square inch) can reduce both shallow and deep compaction. Though these results may be disputed, it is a good idea to minimize both axle loads and ground pressure.

Additional research has shown that track-type tractors have a less detrimental effect on soil properties than equal-powered four-wheel-drive (4WD) tractors with bias ply dual tires. There are indications that 4WD tractors with properly inflated radial tires cause less compaction than track vehicles. By optimizing inflation pressure or using tracks rather than tires, compaction can be minimized.

Managing equipment can help minimize vehicle-induced compaction. Normal tillage will typically remove shallow compaction caused by the tractor. However, close to planting time, tillage tends to get shallower and less effective in removing compaction. Using equipment that contributes to the compaction problem should be avoided when possible. Reducing the number of trips over a field will reduce the area being compacted.

Soil compaction remediation

If soil compaction is a problem, a remedy needs to be determined. Once an implement has been selected to treat compaction, timing becomes important.

Tillage to alleviate compaction should be done when the soil is dry. If the soil is too wet, more compaction could be created. For best results, the soil has to be dry enough to easily shatter. This typically occurs after harvest for most crops.

The type of compaction should also be considered. If conservation tillage is a goal, an implement that doesn't bury much residue is useful. Also, consider the following crop, particularly if subsoiling is needed. Once soil is ripped, it takes some time for it to settle back into place so a seedbed can be prepared. Freezing and thawing during the winter can sometimes break up compaction, particularly if the compacted layer is near the soil surface. Though this is not reliable in some years, it certainly helps in others. Examples of "old" compaction (more than 50 years) are known to exist under pastures.

To treat a specific problem, prescription tillage is needed. Depth of the compacted layer needs to be determined. If it is fairly shallow, less than 10 inches, treat it with a chisel plow. Chisel plows can cause enough soil shattering and are typically capable of operating at depths of 10 inches. However, make sure the chisel gets below the compacted layer and does not ride on top of it. If the problem is deeper, ripping or subsoiling the field will help. Prevention of shallow compaction is more difficult for no-till farmers as they usually do not use tillage to remove it.

Deep compaction can be removed by subsoiling. However, this is an energy intensive, expensive operation. Unless compaction is severe, this cost is often not easily recovered. Deep-rooted crops like alfalfa will help alleviate deep compaction over time.

Summary

The best cure for compaction is to avoid it. Once compaction is a problem the situation is not easily corrected. Compaction can best be found with a shovel. Remember, if at all possible, stay off wet soils, reduce the number of tillage passes, vary tillage depth and, select noncompaction prone equipment.

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