OKLAHOMA COOPERATIVE EXTENSION SERVICE

Soil Compaction and Crusts

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Soil compaction has become more of a problem in Oklahoma soils due to increased equipment size, reduced use of crop rotations, and intensive grazing of cropland. Compaction occurs when soil particles are pressed together, reducing the pore space which increases the bulk density. It occurs in response to pressure exerted by field machinery and animals. Compaction restricts rooting depth, which reduces the uptake of water and nutrients by plants. It decreases pore size, increases the proportion of water-filled pore space at field moisture, and decreases soils temperature. This affects the activity of soil organisms by decreasing the rate of decomposition of soil organic matter and release of nutrients. Compaction decreases infiltration, thus increasing runoff and the hazard of water erosion.

How can compacted soils be identified?

Compacted soils usually have a "platy" or weak structure or a massive condition. They also have a high resistance to penetration. Tillage is often difficult because of higher bulk density associated with compaction. Roots are restricted, flattened, turned under, and stunted. The significance of bulk density depends greatly on soil texture. Rough guidelines for minimum bulk density at which a root restricting condition will occur for various soil textures are shown in Table 1.

Why is compaction increasing?

Larger equipment. More powerful equipment with larger tires allow soil to be worked before it's completely dry. Even with wider tires, heavier axle loads cause greater compaction.

Larger fields. Larger fields require larger equipment. With several textures of soil, some parts of the field may be worked too wet and will cause compaction. Years ago, the same area may have been in three or four fields. Each were worked only when the area was ready.

Repetitive tillage practices. Continuous cropping often results in plowing or tilling at the same depth at the same time of the year. This can cause a hardpan or compaction layer in the soil that will interfere with root penetration.

Over-use of disc. While the disc requires less horsepower to move the most soil, it is a compacting tool. The edges of the disc blades exert tremendous pressure on the subsurface at the point of contact.

How does the problem develop?

Effect of compaction on porosity. During compaction, soil aggregates are crushed and soil particles are packed closer together and literally squeeze out the pore space.

Table 1. Average minimum bulk densities that restrict root penetration in soils of various textures.

Texture	*Bulk Density g/cc*
Coarse, medium, and fine sand	1.80
Loamy sand and sandy loam	1.75
Loam and sandy clay loam	1.70
Clay loam	1.65
Sandy clay	1.60
Silt and silt loam	1.55
Silty clay loam	1.50
Clay	1.40

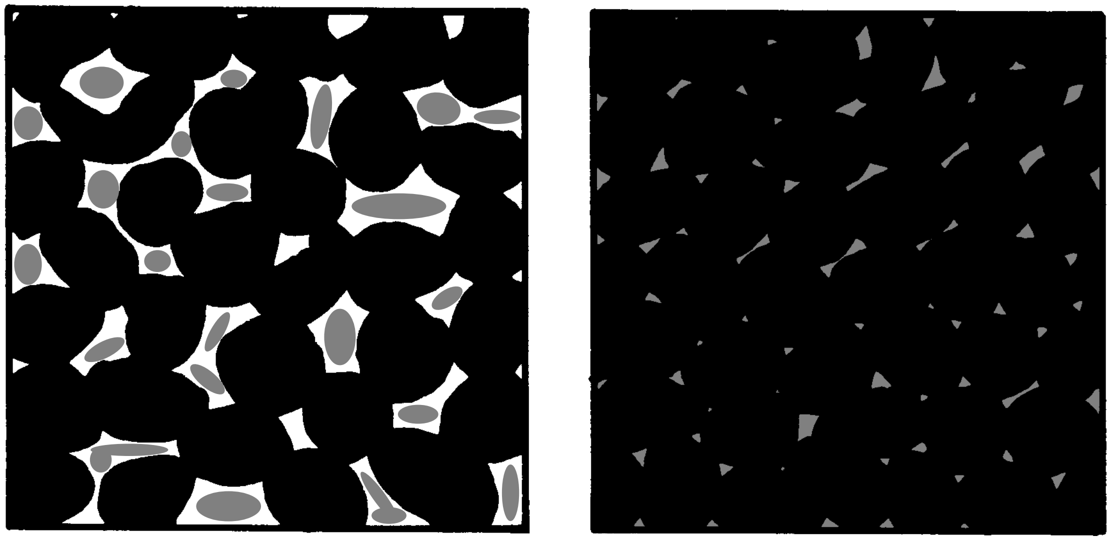
Instead of the ideal 50 percent, compacted soils may have only 30 percent pore space. Larger pores that best carry air and water generally are lost first. As large pores collapse, smaller pores form, but they are less efficient. This leads to slower water infiltration and poorly aerated soils. Poor aeration limits root growth and nutrient uptake. Figure 1 illustrates the effects of compaction on pore space.

Effect of compaction on bulk density. Any compaction that reduces air space increases bulk density or weight of dry soil in a given space. This is one way to measure compaction.

Effect of compaction on soil strength. Like bulk density, soil strength, or its resistance to penetration and displacement, increases with compaction. Increased soil strength limits root penetration and boosts tillage power requirements. It is usually measured by a penetrometer, which indicates vertical differences in compaction. Field determinations can be made by forcing a push-rod into the soil.

How do soil factors affect compaction?

Soil texture. Soil of any texture will compact—sand, silt, or clay. Soils made up of a uniform mixture of sand, silt, and clay compact more than soils made up of particles of about the same size. The reason being that soil pores become filled with the smaller particles. Moderately coarse soils such as sandy loams are most susceptible to compaction.



Uncompacted Compacted

Figure 1. The effect of compaction on pore space. White space is air, gray areas represent moisture.

Soil moisture. Moisture content has the greatest influence on the amount of compaction produced by a given pressure. Water acts as a lubricant, so soil particles are easily rearranged and jammed together more tightly when wet than under dry conditions. Maximum compaction occurs at moisture content near field capacity or when small and medium pores are filled with water. The higher the moisture content, the lower the pressure needed to cause compaction. The greater the pressure, the lower the moisture content at which compaction occurs. Figure 2 shows the effect of soil moisture on depth of compaction under a uniform load.

Organic Matter. Generally, the higher the organic matter of a soil, the less the compaction. First, the organic matter promotes coarser and stronger soil aggregates. At

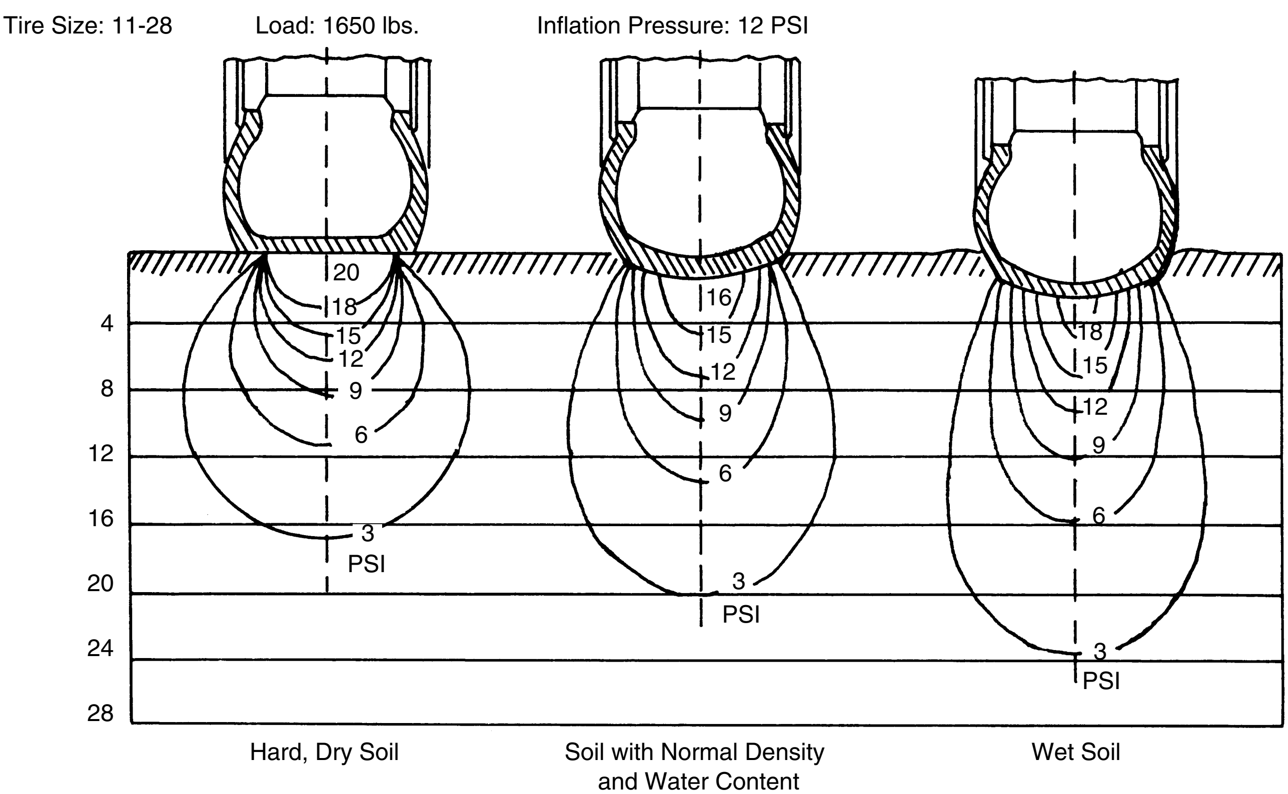


Figure 2. The effect of soil moisture on depth of compaction under a uniform load.

lower moisture levels, aggregates stick together, maintaining larger pores. Second, organic matter is less dense than mineral components of the soil. Organic matter acts like small styrofoam beads.

Plant symptoms of compaction

Compacted soils will affect crop production, because compacted soils are an inferior medium for plant growth. The following symptoms can be caused by disease and other plant stresses, but compaction is often the culprit.

- Slow or poor plant emergence and thin stands can result from compacted soils with increased strength. Often, the surface structure is broken down and a surface crust develops. Seedlings have a difficult time penetrating the soil. As a result, root growth and elongation can be constricted. Generally, this is the result of over-preparation of the seedbed.
- Uneven early growth in the form of tall and short plants in adjacent rows can suggest uneven compaction. It also may reflect restricted root growth due to compacted layers or not enough oxygen for root respiration and soil microorganism activity.
- Off-colored leaves may reflect nutrient deficiencies brought on by compacted soil, restricting root growth, and water movement. Nitrogen starvation is one of the most common symptoms.
- Abnormal rooting patterns can suggest compaction. A shallow, fibrous root system running horizontally above a compacted layer is a frequent symptom. Roots in compacted soils are often flattened.
- Premature drought stress often indicates a compaction problem. A shallow, restricted root system cannot utilize stored subsoil moisture or plant nutrients below a compacted layer.

Methods of determining compaction

There are several methods available when determining soil compaction. Some possiblities are listed below:

- **Knife blade penetration when soil is dry.** Dig a hole in the suspected area at least two feet deep. Leave one side of the hole free of shovel marks. Press a knife blade into the undisturbed side every inch or two, starting at the top. Any difficulty penetrating the soil is probably evidence of compaction.
- **Plant rooting patterns.** Observe the side of the hole for the location and predominance of roots at different depths. Look for masses of roots running horizontal and the absence of roots below certain depths. This is also good evidence of compaction.
- **Soil sampling tube or steel rod.** Simply push the tube into the soil and note resistance.
- **Penetrometer.** This is a pointed steel rod with a gauge that records the pressure needed to penetrate the soil. It provides specific readings, but requires adjustments for moisture. It's reading must be carefully interpreted.

Correcting compaction problems

The best cure for compaction is to avoid it! Natural weather forces such as wetting-drying cycles, freezing-thawing, and expanding-contracting Oklahoma clays can help alleviate compaction by restoring some of the soil porosity.

- **Delay tillage until the soil surface is dry.** A good rule of thumb is that soil squeezed in your hand and then tossed about should fall apart. If not, it is too wet to till.
- **Reduce your tillage trips.** Combine tillage trips or settle for a less than perfect seedbed. Modern drills and planters operate well under today's minimum tillage conditions.

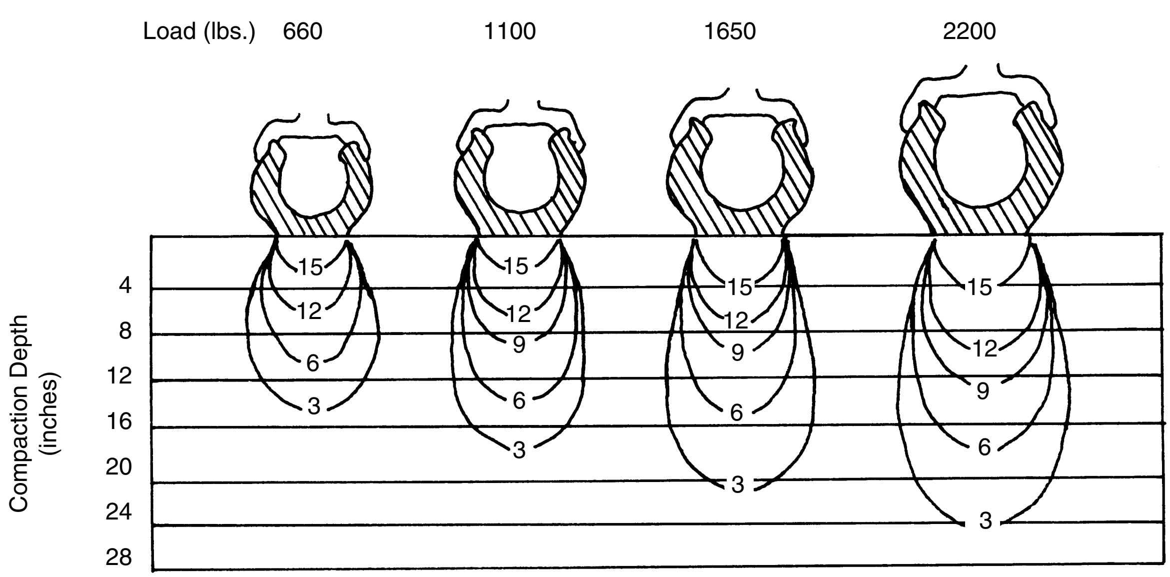


Figure 3. The effect of various tractor loads on soil compaction.

- **Vary the tillage from year to year and restrict the use of disc plows.** Use chisels more often than plows to do primary tillage. Chisels require somewhat more power than plows, but leave more residues on the surface. In addition, they shatter and loosen the soil more.
- **Substitute lighter equipment for heavier.** Often, this is not possible unless you are considering a total change in your farming operation. Minimum and no-till equipment usually pulls easier and requires less horsepower per foot of width. As a result, smaller tractors may be used. Figure 3 shows how varying tractor loads affect soil compaction.
- **Reduce surface pressure with wider tires and duals.** The use of flotation or wider tires and duals do not lessen the amount of total compaction. They just spread compaction out horizontally at a shallower depth. The possible advantage is that regular tillage equipment can be used to shatter the compaction layer. Figure 4 shows how wider tires distribute pressure.
- **Subsoil if compaction is deep.** Subsoiling is an expensive, fuel consuming tillage operation, so be sure subsoiling is necessary. Research at OSU suggests that few Oklahoma soils have compaction zones deep enough and with high enough bulk densities to warrant subsoiling. If subsoiling is done, it is most effective if done when the soil is dry.

Soil crusts

Crusts are relatively thin (1/4 - 1/2 inch thick), massive, and composed of somewhat continuous layers on the soil surface. These layers restrict water movement, oxygen diffusion, and seedling emergence, especially of non-grasses. The crusts can also affect water and wind erosion and reduce surface water evaporation. Crusts are created mainly by the breakdown of soil aggregates from flowing water and raindrop impact.

The water moves clay downward a short distance, leaving a concentration of sand and silt at the soil surface. This condition is usually temporary, with the soil below the crust loose. The problem can be corrected by maintaining a plant or crop residue cover to reduce rainfall impact. A residue cover will also increase soil organic matter and improve soil aggregation. The use of a rotary hoe or row cultivator will shatter crusts and increase seedling emergence.

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