SOIL COMPACTION SYMPTOMS, CAUSES, CORRECTION, AND PREVENTION

CONSERVATION JOB SHEET - Agronomy Series 324.1

WHAT IS SOIL COMPACTION?

Soil compaction reduces pore space, decreases water infiltration, increases runoff, and restricts root growth. Crop yield reduction due to soil compaction depends on the degree of stress the plant experiences during the growing season (Harrigan, 1992).

Surface compaction is described in research literature as being in the top 12 inches of the soil profile (Voorhees, 1987).

Subsoil compaction occurs deeper than 12 inches in the soil profile. Compaction in the subsoil is a function of the total equipment axle load of farm equipment when used on the field.

There are two types of visual and measured symptoms of soil compaction: soil symptoms and plant symptoms.

Soil symptoms include:

- Increased bulk density (clods and crusting).
- Less porosity (no air and slower infiltration).
- Wetter soils (slow to dry).
- “Dead” soil (light color and lacks organic matter).
- Soil structure is platy (poor) verses good soil structure that is granular or blocky.
- Tillage pan (horizontal compaction) below soil surface.
- Bald clay knobs on hill tops and side slopes (poor plant stands and barren slopes).
- Increased water erosion (quicker runoff).
- Uneven planting depth due to soil clods (results in poor plant stands or uneven emergence).

Plant response to compaction depends on soil conditions at the time compaction occurs and the climatic conditions during the next growing season.

Plant symptoms include:

- Uneven stand (slow or failed crop emergence).
- Stunted growth (small plants).
- Discoloring (yellow-and purple plants).
- Lack of a stand and roots (row skips, no brace roots on plants).
- Shallow, flattened, twisted, knotted roots (root balls, horizontal, or “J” roots along soil pans).
- Enhanced drought stress symptoms (pineapple and whorled corn).
- Reduced yield.
WHAT CAUSES SOIL COMPACTION?

Heavy wheel traffic and equipment load on wet soils is the main cause of soil compaction. About 80% of soil compaction is caused by the first trip over the field (Voorhees, 1987).

Other causes include:

- Planting and tilling soils that are too wet (pressure to plant earlier).
- Bigger equipment with wider tires and heavier axle loads.
- Excessive tillage for seedbed preparation.
- Harvesting when the soil is too wet.
- Rutting the soil from hauling manure or spreading fertilizer.
- Depleting of soil organic matter by intensive tillage or crop rotations without legumes.
- Some natural soil properties.
- Intensive tillage that destroys soil structure.

Compaction Effects on Soil Properties:

Surface Verses Subsurface Compaction

- Equipment axle loads of 5 tons will create surface compaction to about 12 inches deep.
- Normal tilling and planting operations with 8-row or greater equipment will exceed the 5 ton axle load.
- Normal tilling and planting operations with 6-row equipment usually does not exceed the 5 ton axle load.
- Axle loads greater than 10 tons create subsurface compaction below 12 inches deep.
- Subsurface compaction below 12 inches reduces effectiveness of tile drainage systems causing ponding and slow soil drainage, drying, and warming.
- Harvest equipment has the greatest potential for causing subsurface compaction. This includes grain carts and harvest trucks.

<table>
<thead>
<tr>
<th>EQUIPMENT AXLE LOADS</th>
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<tbody>
<tr>
<td><strong>EQUIPMENT</strong>*</td>
</tr>
<tr>
<td>Grain Cart (825 Bu)</td>
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<tr>
<td>Wheel Combine, Loaded</td>
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<tr>
<td>4 WD Tractor</td>
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<tr>
<td>MFWD Tractor</td>
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</table>

* Caterpillar, 1996.

Persistence of Surface Compaction

- Freezing and thawing has little effect of eliminating deep subsoil compaction (below 12 inches) and it can persist over winter.
- Mechanical tillage, such as moldboard plowing and chisel plowing, can reduce surface compaction.
- Horizontal tillage equipment may create deeper surface soil compaction (tillage hardpan) than disk blades and sweep blades.

Plant Response to Surface Compaction

Soil research shows that a soil bulk density of 1.3 g/cc is optimum for crop production. Above or below this level, crop yields may be less. However, optimum yields depend on soil and plant characteristics, and growing season climatic conditions (Robertson et. al., 1976). See Table 1, page 6, for guidance on bulk density by soil type.

Effect of Climate on Surface Soil Compaction and Crop Yield Response (0-12 inches deep)

If farming a compacted soil, “A dry year will scare you. A wet year will starve you.”

Crops can tolerate a higher compacted soil during dry conditions than during wet conditions.

For example, soil compaction research in Minnesota on soybeans found that when May-August rainfall exceeded 14 inches, soybean yields were significantly decreased in compacted soil. However, if May-August rainfall was less than 14 inches, soybean yields were drastically increased by the presence of inter-row wheel traffic (Voorhees, 1987).

Research Results from Minnesota Using Corn Yield to Predict the Effect of Climate on Subsurface Soil Compaction (Greater than 12 inches deep)

- On soils with 10% clay or less compacted when wet using axle loads of 10-20 tons, corn planted the following year showed only a slight yield reduction. On these soils, subsoil compaction may last only one year (Voorhees, 1987). In Michigan, soils with 10% clay or less are classified as MSU Soil Management Groups 5.0 or 4.0 soils.
• On soils with greater than 30-39% clay compacted when wet using axle loads of 10-20 tons, it took 3-5 years of normal freezing, thawing, wetting, and drying to bring corn yields back to normal (Voorhees 1987). Soils with 30-39% clay are classified as MSU Soil Management Group 1.5 soils.

• On soils with 40-70% clay and compacted using axle loads for 10-20 tons, corn yield reductions occurred for 7 years regardless of annual freezing and thawing. Research in England on similar soils showed that subsoiling 14 inches deep showed no effect on corn yield. In fact, deep tilling of such soils can increase bulk density and pack the subsoil again (Voorhees 1987). Soils with 40-70% clay are classified as MSU Soil Management Group 1.0 or 0 soils.

Effects of Soil Texture

Soil texture influences how a given crop responds to the degree of soil compaction.

• Soil compaction increases on poorly drained or wet, fine textured soil with each additional farm equipment pass.

• As the soil texture becomes finer and wetter, crop yields become more sensitive to compaction.

What are the Corrections for Soil Compaction?

First, identify the depth of the soil compaction layer.

According to Dr. Gary C. Steinhardt, Purdue University, “to minimize or correct soil compaction you need to ... identify the nature and extent of the problem in the field,” (Steinhardt, 1985).

There are two methods to determine the presence of soil compaction and depth of the compaction layer or tillage pan. These procedures work best when soil is moist to the touch below the surface.

One way is to dig a hole and observe the soil structure for compacted, platy soil layers. Dig a hole 2 feet deep and look for wormholes and old root channels. With a strong bladed knife stuck 3 inches deep in the sidewall near the bottom of the hole, slowly pull the knife up until it is nearly impossible to lift higher. Your hand will feel resistance. This is the bottom of a compaction pan. Determine the depth of the pan by following the same procedure from the soil surface.

A second way is to use a soil penetrometer. This is thin rod with a spring-loaded gage that records the pressure needed to penetrate the soil. Push the penetrometer slowly into the soil until it becomes difficult to do so. Stop and measure the depth. Then push the penetrometer deeper until it becomes increasingly easy to penetrate the soil. This method determines the width and depth of soil compaction.

Determine Soil Moisture Conditions – Plastic Limit

Plastic limit is the soil moisture content at which soil material can be deformed without rupture or soil particles start to slide over each other. At or above (wetter than) the plastic limit significant soil compaction will occur. Below (drier than) the plastic limit minimal compaction will occur.

Procedure (Hand Rolling Method)

1. Take about 1 tablespoon of soil, sufficient soil to make a 1/8 inch (3 mm) rod (rope, thread, wire) between fingers and palms with little or no rod extending outside of fingers or palms.

2. Squeeze and form the soil into an ellipsoidal-shape mass.

3. Roll this mass between the fingers or palms with just sufficient pressure to roll the mass into a rod of uniform diameter along its length. Roll out between 40 and 45 strokes per 30 seconds, counting a stroke as one back and forth motion. The sample must be rolled into the 1/8 inch (3 mm) rod in about 30 seconds. If more time is taken, some soil water will be absorbed by fingers and palms.

If the rod crumbles under the pressure required for rolling and the soil cannot be rolled into a 1/8 inch (3 mm) rod, the soil is drier than the plastic limit.
4. If the soil can be rolled into a 1/8 inch (3 mm) rod, the soil is wetter than the plastic limit.

Determination of the plastic limit is independent of soil texture. If the soil is too granular to form a rod even when very moist, then it is not very susceptible to compaction and smearing.

Using Deep Tillage (Vertical Tillage)

Determine the plastic limit of your soil using the above procedure. Other observations or rules of thumb: If the soil makes a ball in your hand at the depth of tillage it’s too wet to till. Or if shiny ribbons of soil peel off the equipment shanks as tilled, then the soil is too wet or tillage is too deep.

Once the depth and extent of the compacted zone is determined, there are a number of options for removing this yield robbing soil factor.

Use a subsoiler or deep till with slots if the compacted layer is deeper than 12 inches. Set either implement to run about 1/2 to 1 inch below the bottom of the compacted layer.

Plant a deep rooted crop like alfalfa to break up the hard pan.

Deep Tillage with a Subsoiler

For farmers that till, subsoil at least 12 inches deep when the soil is dry enough to shatter the hard pan. If the soil moisture is correct for every inch of subsoil shank depth, the soil should shatter out at a 45-degree angle or 2 inches per 1 inch of depth (2:1). A lesser angle of shatter might indicate the soil is too wet to subsoil and may create a new tillage pan at the new deep tillage depth. In theory, dry soil breaks up and shatters much better then wetter, plastic soils (Harrigan, 1992).

Avoid any secondary tillage operations in the fall after subsoiling. Dr. Gary Steinhart, Purdue University, says 80% of compaction is caused by the first trip over the field. If the soil is compacted by tillage and wheel traffic soon after subsoiling, the soil structure problem may be more severe than before the initial deep tillage. Staying out of the field just one more day in the spring could reduce compaction (Steinhart, 1979).

Deep Tillage with Vertical Slot Tillage or Zone Tillage

Another option to correct compaction before no-till is to deep zone-till. In Don Schriefer’s book, Tillage in Transition, deep compaction from rutting or tilling soils that are too wet, is corrected by locating the depth of the tillage hardpan, determining its thickness, and tilling a narrow slot through the pan when the subsoil is damp, i.e., (damp: soil sticks together, but easily breaks apart with pressure).

Schriefer recommends a zone builder to aerate the soil, improve drainage, and strengthen soil structure. Zone tillage at the correct soil moisture will smear the subsoil and compact each side of the shank so there is a permanent crack in the subsoil. More recently, some agronomists refer to this tillage as vertical tillage. It is important to control traffic in vertical tillage to prevent wheel track axle loads from closing the subsoil slot, i.e., do not drive over the slots, if possible.

It is also important to plant the crop near this slot to allow the crop roots to penetrate below the compacted soil tillage pan. The next crop can then follow the old root channels. This will help ensure that the subsoil zone remains open so roots can penetrate deeper for moisture and nutrients while remaining in an air-filled environment.

With deep tillage, soil aeration, and controlled traffic:

- The roots replace the slots and keep the root channels and worm holes open for improved drainage into the subsoil.
- The narrow slots serve as future expansion zones for freezing and thawing forces to keep the zone-tilled slot open.
- Microbial soil activity is improved due to aeration and a carbon food source (deep roots).

Two years of deep slot tillage, followed by driving on soils only when it’s dry or the right moisture for tillage, should prevent soil compaction from occurring.
Deep slots ahead of soybeans on low wet ground without tile drainage “provided improved drainage compared to no-till for soybean growth during the extraordinary wet years, such as the one encountered in 2004.” As a result, after 2 flooding events in the spring, the seed germination and plant stand at maturity was considerably higher on slots compared to the no-till plot (Dierberger, 2005).

**Soil Compaction Symptoms Include**

*Robertson, et. al., 1976*

1. Clods, lumps, and lifeless soil.
2. Standing water, even if well tilled.
3. Excessive soil erosion, runoff, or gullies.
4. Tillage pans or visual dense layers.
5. Slow drying that prevents field entry.
6. Surface crusting.

![Soil compaction symptoms image](image_url)

Navy bean root parallel to hard pan indicates depth of surface soil compaction. Source: NRCS, Grigar, Tuscola County, MI.

**Plant Symptoms of Compaction Include**

*Robertson, et. al., 1976*

1. Yellowing, purple leaves.
2. Uneven stands.
3. Flattened roots parallel to surface or tillage pan.
4. Reduced yields even with all the right inputs (variety, fertility, weed control, etc.).
5. Stunted growth.

![Plant symptoms of soil compaction image](image_url)

A soil penetrometer is one tool to check soil compaction depth. Source: NRCS, Grigar, Midland County, MI.

**What are the main causes of soil compaction?**

1. Working soils too wet or early.
2. Big equipment size and incorrect tire pressure.
3. Equipment axle loads greater than 5 tons/axle, typical of: grain carts, manure hauling equipment, fertilizer spreaders, or combines.

**Soil Compaction Prevention Methods Include**

1. Providing adequate drainage.
2. Using legumes and small grains in rotations.
3. Staying off wet soils.
4. Farming with longer crop rotations or with more high residue crops in rotation.
5. Running combine wheels on harvest rows.
6. Alternating row centers in no-till corn allows the wheels to be supported on the decaying row.
7. Reducing wheel traffic with no-till, zone till, strip till, ridge till, or vertical till.
8. Combining low axle loads with low tire pressure to achieve the largest reduction in soil compaction.
9. Adding organic material (manure) to stimulate soil life, especially in low organic matter soils.
10. Substituting lighter equipment for heavier, whenever possible.
11. Avoiding use of a disk.
12. Avoiding working soil when it’s too wet.
14. Using a controlled traffic system.
15. Reducing surface pressure with wider tires or duals.
16. Using high flotation rubber tracked equipment.
17. Narrow strip cropping.
### Table 1: Bulk Density (g/cc) by Soil Texture that Root Restriction can Occur

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Bulk Density (g/cc)</th>
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</thead>
<tbody>
<tr>
<td>Coarse, medium, and fine sand and loamy sand other than loamy fine sand</td>
<td>1.8</td>
</tr>
<tr>
<td>Very fine sand, loamy very fine sand</td>
<td>1.77</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>1.75</td>
</tr>
<tr>
<td>Loam, sandy clay loam</td>
<td>1.70</td>
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<tr>
<td>Clay loam</td>
<td>1.65</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>1.60</td>
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<tr>
<td>Silt, silt loam</td>
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<tr>
<td>Silty clay loam</td>
<td>1.50</td>
</tr>
<tr>
<td>Silty clay</td>
<td>1.45</td>
</tr>
<tr>
<td>Clay</td>
<td>1.4</td>
</tr>
</tbody>
</table>


Prepared by: Jerry Grigar, NRCS, Michigan State Agronomist; Dr. Jerry Lemunyon, NRCS, Conservation Agronomist, Fort Worth, Texas; Dr. Delbert Mokma, MSU, Crop and Soil Sciences, East Lansing, Michigan.

**References:**


Elanco Products Inc., *Don't let Soil Compaction Squeeze Your Profits*, EA-4024.


