SOIL COMPACTION SYMPTOMS, CAUSES, CORRECTION, PREVENTION

CONSERVATION INFORMATION SHEET - Agronomy Series 324

Natural Resources Conservation Service

Michigan

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, Sweden 1985).

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

Subsoil compaction is referred to as being deeper than 12 inches in the soil profile. Compaction in the subsoil is a function of the total equipment axle load of farm equipment.

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

Soil symptoms include:

- Standing surface water (frog ponds)
- Increased bulk density (clods and crusting)
- Less porosity (no air)
- Wetter soils (slow to dry)
- Dead soil (light color lacks organic matter)
- Poor soil structure (soil is platy versus granular or blocky)
- Tillage pan (horizontal compaction)
- Bald clay knobs on hill tops and side slopes
- Increased water erosion
- Uneven planting depth due to soil clods

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 (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 corn)
- Reduced yield

WHAT IS THE CAUSE OF SOIL COMPACTION?

Heavy wheel traffic on wet soils is the main cause of soil compaction. About eighty percent 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
- Depletion of soil organic matter by intensive cropping and crop rotations without legumes
- Some naturally occurring soil properties

Compaction Effects on Soil Properties: Surface Versus Subsurface Compaction

- Equipment Axle loads of 5 tons will create surface compaction to about 12" deep.
- Normal tilling and planting operations, with eight row or greater equipment, will exceed the 5 tons axle load.
- Normal tilling and planting operations with six-row equipment usually does not exceed the 5 tons axle load.
- Axle loads greater than 10 tons create subsurface compaction below 12" deep.
- Subsurface compaction below 12" reduces effectiveness of tile drainage systems, causing ponding and slow soil drainage and drying.
- Harvest equipment has the greatest potential for causing subsurface compaction.

Example Equipment Axle Loads

EQUIPMENT*	AXLE LOAD (tons)
Grain Cart (825 Bu)	28
Wheel Combine, Loaded	17.1
4 WD Tractor	12.7
MFWD Tractor	7.7

* Caterpillar *Managing Soil Compaction,* 1996.

Persistence of Surface Compaction

- Freezing and thawing has little effect of eliminating compaction, especially deep subsoil compaction and it can persist over winter.
- Mechanical tillage such as moldboard plowing and chisel plowing can reduce surface compaction.
- Tillage equipment may cause deeper soil compaction (tillage pan).

Plant Response to Surface Compaction

Researchers generally consider a soil bulk density of 1.3 g/cc as 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 1976).

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

Crops can tolerate a more highly compacted soil during dry conditions than during wet conditions. *"A dry year will scare you, a wet year will starve you." (Michigan farmer).*

For example, soil compaction research in Minnesota on soybeans found that when May-August rainfall exceeded 14 inches, soybean yields were significantly decreased by compaction. 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).

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

- On soils with 10 percent clay or less, compacted when wet using axle loads of 10-20 tons, corn showed only a slight yield reduction the following crop year. On such soils, subsoil compaction may last only one year. These soils would be any soil series classified as MSU Soil Management Groups 5.0 and 4.0.

- On soils with greater than 30 percent clay, compacted when wet using axle loads of 10-20 tons, corn took 3-5 years to bring yields to normal via freezing, thawing, wetting, and drying. These soils would be in MSU Soil Management Group 1.5.

- On soils with 40-70 percent clay, compacted using axle loads for 10-20 tons, corn yield reductions occurred for 7 years in spite of annual freezing and thawing. Research in England on similar soils showed that subsoiling 14" deep had no effect on corn yield. In fact, deep tilling of such soils can increase bulk density and pack the subsoil again (Voorhees 1987). These soils would be in MSU Soil Management Groups 1.0 and 0.

Effects of Soil Texture

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

- Soil compaction increases on high moisture, fine textured soil with additional farm equipment passes.
- 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 soil compaction and the depth of the compaction layer or tillage pan.

- One way is to dig a hole two feet deep and look for wormholes and old root channels. With a strong bladed knife stuck in 3 inches deep near the bottom of the hole, slowly pull the knife up the sidewalls of the hole until it is nearly impossible to lift higher; i.e. your hand feels resistance. This is the easiest way to find the bottom and depth of a compaction pan.

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

Determine Soil Moisture Conditions

With either method, the soil must have soil moisture at or near field capacity (i.e. within the 2-foot depth the soil needs to feel damp to the touch or at the right moisture to till without making wet clods with tillage.) If either method is used when it is too wet or too dry, it will provide a false reading of the width and depth of the horizontal compaction pan. **Rule of Thumb: When soil conditions are right to plow it is a good time to check for soil compaction.**

Use of Deep Tillage (see Deep Tillage, Code 324)

Once the depth and extent of the compacted zone is determined, then there are a number of options for removing this compaction.

Subsoil or zone-build 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.

There currently are two opinions when the soil is the right moisture to correct compaction (subsoil vs. zone-build).

For farmers that till, subsoil below 12 inches deep when the soil is dry enough to shatter the hard pan. For every inch of subsoil shank depth, the soil should shatter out at a 45-degree angle or two inches per inch of depth (2:1) if the soil moisture is correct. 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 than wetter, plastic soils (Harrigan).

Avoid secondary tillage operations after subsoiling in the fall. Dr. Gary Steinhardt, Purdue University, says 80 percent of compaction is caused by the first season's 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. Often staying out of the field just one more day in the spring could reduce compaction. **Rule of Thumb: If the soil makes a ball in your hand at the depth of tillage, it's too wet to till. Or if you see shiny ribbons of soil peeling off the equipment shanks as you till, it is too wet or you are tilling too deep.**

Another option to correct compaction before no-till is to deep zone-till. In Don Schriefer's book, *Tillage in Transition*, deep compaction is corrected by locating the depth of the tillage pan, determining its thickness, and tilling a narrow slot through the pan when the subsoil is damp.

Zone till was developed by inventor Ray Rawson, Farwell, Michigan, and his deep till tool is called a zone builder.

Schriefer recommends a zone builder to aerate the soil, and improve drainage and soil structure. Zone tillage

at the right soil moisture will smear the subsoil and compact it on each side of the shank so there is a permanent crack in the subsoil. **It is important to control traffic in this system 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 on this slot to get crop roots to penetrate below the pan so the next crop can follow the old root channels. This will help ensure that the subsoil zone remains open so roots can penetrate deeper for moisture and nutrients in an air filled environment.

With deep tillage soil aeration and controlled traffic:

- The roots replace the slots and keep the root channels and wormholes 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 in the soil open.
- Microbial soil life activity is improved.

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