
Don't let
SOIL COMPACTION
Squeeze Your Profits

Soil Compaction:

Acknowledgement

Dr. Gary C. Steinhardt, Associate Professor of Agronomy, Purdue University, for his technical assistance in preparing this booklet.

When you pack your soils excessively, you may not only be squeezing out air space — you may be putting the squeeze on your profits. The results of soil compaction can be costly as you'll see when you read on. You'll also learn how to identify and reduce or correct soil compaction.

Compaction is increasing

Reports across the Midwest indicate that soil compaction is becoming an increasing problem. According to Dr. Gary Steinhardt, soil compaction specialist at Purdue University, about 7.5 million of Indiana's 12 million acres of row cropland are susceptible to severe compaction. He thinks compaction to some degree is a problem on many of these soils.

Lance Murrell, a Midwest consulting agronomist, says soil compaction has become our number one soil problem.

Once thought to be only a problem in the low-organic soil of the South, compaction is now evident in states such as Minnesota and Michigan. Dr. L. S. Robertson, Professor of Soil Science at Michigan State University, says a recent survey in Cass County in southern Michigan was revealing. Excessive compaction was seen in 95 percent of the soybean fields and 90 percent of the corn fields surveyed!

Why compaction is increasing

Pressure to plant earlier. Agronomists have sold you on the idea of planting earlier to maximize yields. But, even though you have larger equipment, you're farming more acres. So you take that big equipment into the field earlier, when soils are still marginally wet. That's when soils compact the most.

Bigger equipment. More powerful equipment with bigger tires let you work soils before they're dry enough. Even with wider tires, heavier axle loads cause greater compaction.

An Increasingly Costly Problem

Bigger fields. Today's expansive fields, needed to match your larger equipment, may contain several textures of soils and varying drainage problems. Working the whole field with some of it dry enough and some marginally wet, compacts the too-wet areas. Years ago, the same area may have been in four fields, each worked only when it was ready.

Repetitive tillage practices. With continuous corn or a corn-soybean rotation, you may plow or till at exactly the same depth at the same time each year. This can cause a hardpan, or compacted layer, in the soil to interfere with root penetration.

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

Rotation without meadow crops. Few farmers include sod-forming crops in their rotations that would add organic matter, penetrate subsoils better and require less tillage. Consequently, soils are more prone to compact.

The result of increasing compaction is lower yields and higher costs of production.

How compaction increases costs

Compacted soils are harder to till. Research in Illinois showed that 92 percent more power was required to plow a severely compacted soil. Larger more powerful tractors required to till compacted soils, in turn, cause *more* compaction. It's a costly cycle.

Poor drainage of compacted soils can cost you in planting delays and in poor root and plant development. Early crop problems are often mistakenly identified as herbicide or fertilizer injury. These symptoms of compaction reflect inadequate root development which can result in severely depressed yields, particularly with drouth later in the growing season.

Finally, compaction delays maturity which results in higher moisture content of grain at harvest along with the lower yields.

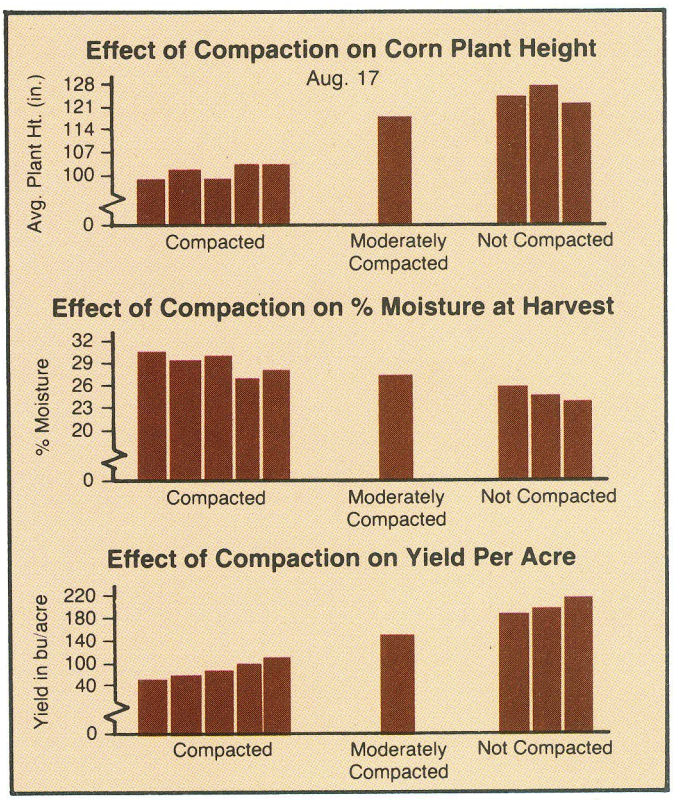
Research proves costliness of compaction

In 1982 corn experiments, Purdue University scientists showed that compaction reduced stand 20 to 30 percent, plant height a third to one-half and yields by about 19 percent. Yields were 160 bushels per acre on non-compacted soil; only 130 bushels on compacted plots.

Corn grown in compacted soil (left) on this Mansfield, Illinois, farm was shorter, had three percent more moisture at harvest and yielded 60 percent less than corn grown in non-compacted soil.

Ohio scientists reported a 30-percent reduction in corn yields when soil was compacted at the 3-6-inch depth. Illinois scientists reported 12 bushels less per acre from compaction of a silty clay loam soil. Also in Illinois, Elanco Products Company researchers demonstrated a 60-percent yield reduction — from 159 bushels to only 96 bushels — due to compaction.

Purdue University experiments on silt loam soils proved that both moderate and severe compaction of the subsoil 1) reduce corn plant height, 2) increase moisture content at harvest, and 3) reduce yields. Details are shown in the charts below.



How the Problem Develops...

As tough as soil is to till, you probably never thought of it as fragile. But it is.

The soil that's the basis for your livelihood is a fragile mixture of solids such as sand, silt, clay and organic matter plus liquids and gases. These components are more or less in equilibrium and tillage tends to disturb them — often to your detriment.

Individual soil particles and moisture form soil aggregates that give soil good tilth. An ideal soil might be 50 percent solid, with the other 50 percent equally divided between air and water in what is called pore space. Pores are important because they allow air and water movement and permit roots to penetrate soil to obtain nutrients and moisture.

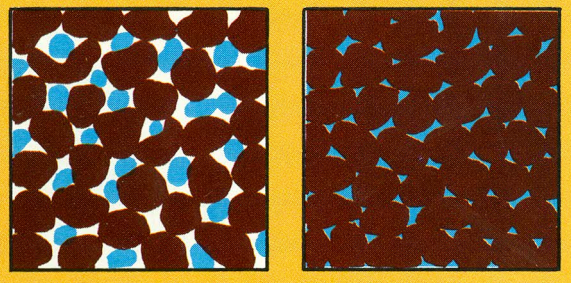
Effects of compaction on porosity

During compaction, soil aggregates are crushed and soil particles packed closer together, literally squeezing out the pore space. Instead of the ideal 50 percent pore space, compacted soil may be only 30 percent pore space.

The first pores to be lost are the larger ones that best carry air and water when the soil is wet.

Effect of Compaction on Pore Space

White space is air,
Blue is moisture



Uncompacted Compacted

As large pores collapse, smaller pores form. But these are less efficient, leading to slower water penetration, poor drainage and poorly aerated soils. Poor aeration limits root growth and nutrient uptake.

Effect of compaction on bulk density

Any compaction that reduces air space increases bulk density or weight of soil in a given space. Scientists measure bulk density by weighing a sample of dried soil. It's one way to measure the amount of compaction.

Effect of compaction on soil strength

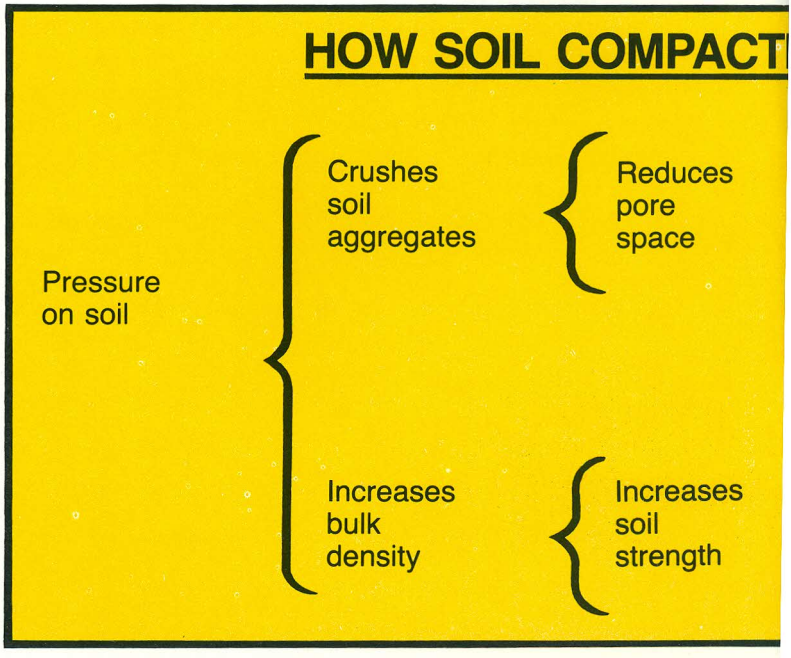
Like bulk density, soil strength, or its resistance to penetration and displacement, increases with compaction. Increased soil strength limits root penetration and boosts tillage power requirements. It is usually measured by a penetrometer which indicates vertical differences in compaction (see photo below).

You need to know about several factors that affect compaction so you can deal with these in tillage operations.

Soil texture

Any soil 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 is that particles of different

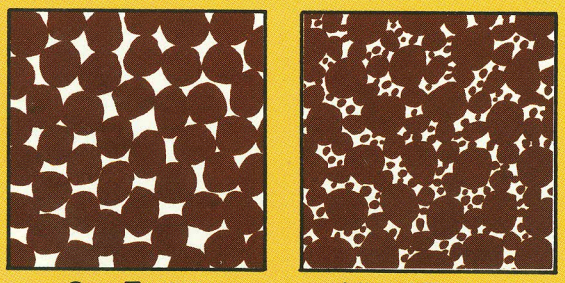
HOW SOIL COMPACT



Recognizing the Symptoms

sizes pack tighter, filling the pore spaces (see following illustration). Moderately coarse soils such as sandy loams are most susceptible to compaction.

Effect of Soil Texture on Compaction



One Texture | Mixed Texture

Soil moisture

Moisture content has the greatest influence on the amount of compaction produced by a given pressure. This is true because water acts as a lubricant and soil particles are easily rearranged and jammed together more tightly than under dry conditions.

Compaction increases to maximum at a moisture content near field capacity (water remaining after drainage due to gravity). This is when fine and medium-sized 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.

Organic matter

Generally, the higher the organic matter of a soil the less the compaction, for two reasons. First, organic matter promotes coarser and stronger soil aggregates. At lower moisture levels these aggregates stick together to maintain larger voids (pores) than if they broke down to their individual particles.

Second, organic matter is much less dense than the mineral components of the soil. Prairie soils with 5-8 percent organic matter are less likely to compact than forest soils with 1-5 percent organic matter.

The Probability of Compaction Chart below summarizes factors that influence susceptibility to soil compaction.

Probability of Compaction

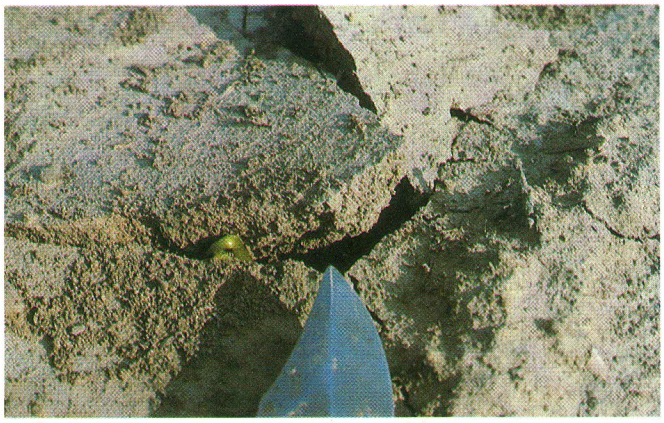
LOW	HIGH
Lower moisture content	Higher moisture content
Soil particles about same size	Soil particles vary in size
High organic matter	Low organic matter
Lighter equipment	Heavier Equipment
Minimum tillage	Frequent tillage
Higher tillage speeds	Lower tillage speeds

ON DEVELOPS	SOIL SYMPTOMS	PLANT SYMPTOMS
Slows exchange of oxygen and carbon dioxide	Reduced water infiltration	Slow crop emergence
Limits water nutrient movement	Standing water/ drainage problems	Uneven stands
Increases water content at expense of air	More surface erosion	Shorter plants
Lowers temperature of soil	Fewer roots in soil profile	Off-color or purple leaf discoloration
Slows root penetration	More compaction resulting from larger equipment needed	Shallow, constricted roots
Increases power requirements		Malformed roots
		Moisture stress

Soil symptoms of compaction

To be able to minimize or correct soil compaction you need to be able to identify the nature and extent of the problem in the field. The following soil conditions indicate symptoms of compaction.

- Surface crusting is the most widespread and evident symptom of a breakdown in surface structure. This may result from over preparation of the seedbed. The result, of course, is often poor crop emergence.



- Standing water may indicate that water infiltrates slowly due to surface crusts or subsurface compact layers. Compaction that reduces large pore space by half will cut infiltration by 16 times, according to research.

  Symptoms of poor tile drainage may reflect a compacted soil layer that prevents water from reaching the tile line.

- Excessive erosion may be due to either surface crusts or subsurface compaction. Excessive runoff on sloping lands may result from slow water infiltration. This can set up a cycle of problems because soil exposed by erosion is even more prone to compaction because of its lower organic matter content.

- Slow decomposition of organic matter due to low oxygen in waterlogged soils may also be a symptom of compaction.

Plant symptoms of compaction

Soil problems caused by compaction are going to show up as symptoms in your crops, since compacted soil is no longer as good a medium for growth. While the symptoms that follow may be caused by diseases or other stresses, compaction is often the culprit.

- Slow plant emergence and thin stands can result from compacted soils with increased strength. Seedlings have a difficult time penetrating this soil and root growth and elongation can be constricted.

  Emergence also may be delayed because compacted soils retain water and wet soils warm more slowly in the spring. In addition, cold, wet soils make seedlings more susceptible to soil-borne diseases. Poor seed is often blamed.

- Uneven early growth in the form of tall and short corn plants can reflect uneven compaction. This symptom can also reflect restricted root growth due to compacted layers or lack of enough oxygen for root respiration and soil microorganism activity.

  Crops grown in compacted soils are generally shorter than normal plants at the end of the season. Herbicides and fertilizers are often mistakenly blamed for the tall-corn-short-corn syndrome when compaction is at fault.

- Off-colored leaves may reflect nutrient deficiencies where compacted soil restricted root growth and water movement. Nitrogen starvation, characterized by yellowing of lower leaves, is one of the most common symptoms.

  Purple corn may result from stress caused by cold weather or compaction as well as limited uptake of phosphorus from the soil. In addition, some hybrid corn varieties are more prone to develop purple coloration than others.

- Abnormal rooting patterns can suggest compaction. A shallow, fibrous root system running horizontally above a compacted layer is a frequent symptom. Roots found in cracks of compacted soil may be somewhat flattened.

- Stressed plants under dry or wet conditions often reflect a compaction problem. A shallow root system that developed in water kept at the surface by a compacted layer or that couldn't penetrate the compacted soil is in trouble when drouth develops. In a wet season, crops may be "starving" for nitrogen in wet, compacted soils even though you applied adequate nitrogen.

How to Minimize or Correct Soil Compaction

When you've identified the symptoms of compaction you need to determine the extent and level of your compaction problem before taking steps to minimize or correct it.

Methods to determine compaction

1. Knife blade penetration when soil is dry. Dig a hole in the suspected area two feet in diameter and two feet deep. Leave one side of the hole free of shovel marks. Press a knife blade into the undisturbed side every two to three inches, starting at the top.

When you encounter difficulty penetrating the soil, this is probably evidence of compaction.

2. Soil sampling tube. Simply push the tube into the soil and note resistance.
3. Penetrometer. This gauge records the pressure needed to penetrate the soil. It provides specific data but readings require adjustment for soil moisture and careful interpretation.

Steps to minimize or correct compaction

Once you've identified the location and extent of your compaction problem, you need to determine the causes so you can prevent its recurrence. What you finally do will depend on your soil, your equipment, your cropping system and your objectives.

1. Delay your first spring tillage. This is discussed first because it's most important. Up to 80 percent of compaction is caused by the first season's tillage trip. One reason is that it's usually completed when the soil is still too wet *at the tillage depth.* Maximum compaction occurs when soils have a moisture content near field capacity.

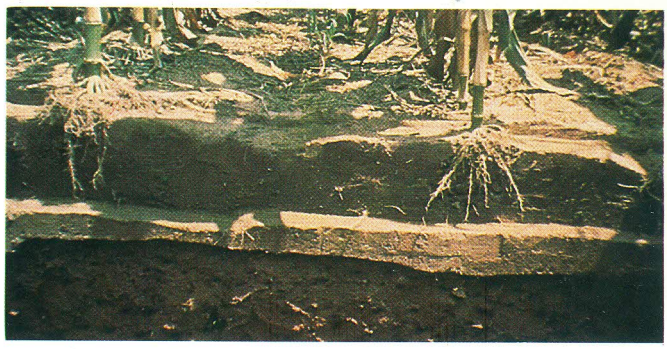
Experts agree that staying out of fields just one more day in the spring could reduce compaction. The soils should be dry enough to resist molding into a compacted mass.

A good rule of thumb is that if you pick up a handful of soil and compact it, then toss it about, it should fall apart. If it doesn't, it's too wet to work.

2. Reduce your tillage passes. This is probably the next most important step you can take to reduce compaction.

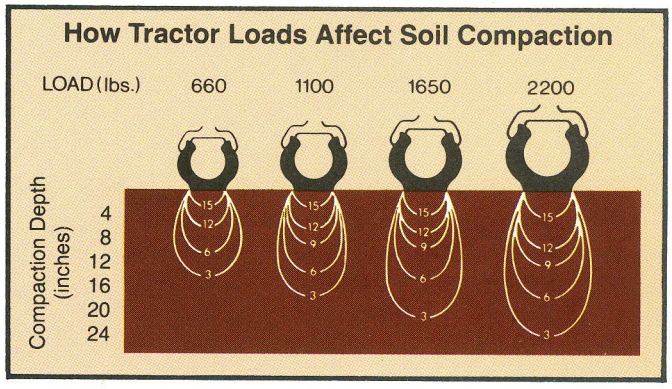
You can do this by using combination tillage tools or by settling for less than a "perfect" seedbed. Modern drills and planters can operate well under today's minimum tillage conditions.

3. Vary the tillage from year to year. To prevent a plow pan or compacted tillage layer (see photo below), plowing one year and chiseling the next would help prevent compaction. Chisels require less power than plows, leave more residue on the surface and have a more shattering or loosening effect on soils.

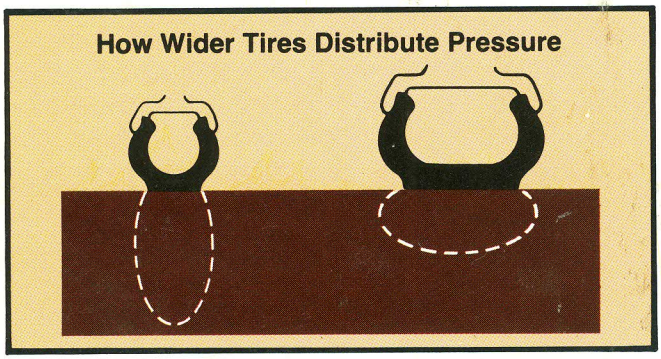


4. Restrict use of the disc-harrow. Since the blades of the disc cause compaction, field cultivators or combination tillage tools are preferable. They also provide good shattering of soils when dry enough. Another advantage of these tools is that they can be operated at faster speeds. Moving equipment across soils faster reduces compaction.

5. Substitute lighter equipment for heavier. This includes mammoth harvesting equipment that can cause compaction in a wet fall. Since the axle load determines pressure on the soil surface, reducing axle load helps minimize compaction. Even bigger tires with increasing axle loads increase compaction. (See illustration below).



6. Reduce surface pressure with wider tires and duals. The use of flotation or wider tires or dual tires doesn't lessen the amount of total compaction. But it does spread it out horizontally at a shallower depth (see illustration below).



The possible advantage is that the regular tillage equipment you already have can be used to shatter this compaction layer. Dual tires also improve traction and reduce slippage. Slippage as low as 15-20 percent can contribute to compaction.

7. Improve your drainage. Since wet soils compact more, anything you can do to improve drainage will let your soils dry out earlier and let you plant quicker with less chances of soil damage. This might include laying more tile or adding sod crops to your rotation.

8. Subsoil if compaction is deeper than 12 inches. For subsoiling to be effective it must be done when the soil is dry enough to shatter the layer. It must also be deeper than the compacted layer.

The most common V-shaped subsoilers are designed to operate 20 inches deep. Each shank requires about 30 horsepower to work to the full depth.

The beneficial effects of subsoiling can last several years if soils are not re-compacted. You need to minimize tillage and traffic to avoid re-compacting the soil.

Freezing and thawing do not correct deep compaction. Subsoils compacted in a 1979 Purdue University experiment still resulted in a corn yield reduction of 25 bushels per acre in 1982.

9. Add organic matter. Organic matter promotes good soil structure by binding aggregates together. When soils are worked too wet, these are not as easily broken down by secondary tillage or traffic.

Add more organic matter by working in crop residues, growing more small grains with grass-like root systems, growing a green manure crop or applying animal manures.

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