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Soil Compaction I Where, how bad, a problem

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Soil Compaction I
Where, how bad, a problem

By Elbert C. Dickey, Thomas R. Peterson,
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Soil compaction is a more common problem now than it was 15 years ago, regardless of the tillage system used. Producers now use heavier tractors, larger implements, bigger combines, earlier spring tillage, reduced tillage, and no-till planting systems.

While all of these have a potential to increase compaction, the major cause of the problem is conducting field operations when the soil is too wet. Most think about tilling wet soils in the spring as being the major problem, but harvesting a too-wet field in the fall can cause just as much compaction. Large combines and auger wagons can have loads exceeding 20 tons per axle.

Continuous no-till has also created concerns regarding soil compaction and potential yield decreases. A study in Minnesota that compared no-till and other tillage systems used for 10 years on a clay loam soil showed the greatest soil density for the no-tilled soil.

A study in Illinois indicated more compaction with no-till and other reduced tillage systems than with moldboard plow or chisel systems.

Generally speaking, no-till is undesirable on a fine-textured soil which has poor internal drainage or on a soil that has marginal tilth at the outset.

On top of the soils themselves, the residue cover with no-till conserves moisture and slows soil drying, which can further complicate the problems of compaction when no-till is used on poorly drained soils.

Editor's Note: Although some soils are less vulnerable than others, most soils can be compacted if the field operations are done at the improper time. This article, first of two on the subject, defines compaction, tells how to measure it, and explains what compaction can do to yields. The second article, to be published in our October issue, will tell how to assess compaction and reduce its effect in individual fields.

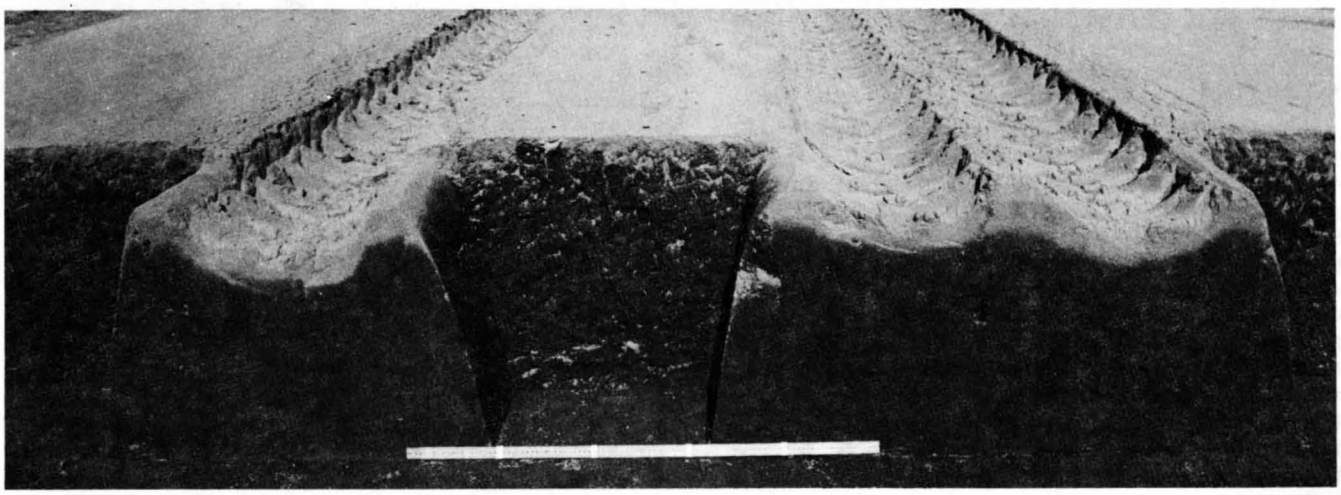
Soils with good structure, high organic matter, and good internal drainage are less likely to have compaction problems. Also, in low-rainfall areas, such as the Great Plains, compaction is less likely to be a problem than it is in areas of more moisture.

The biggest single cause of compaction is the degree of wetness in a field when work is performed in or on that field.

Defining compaction

Compaction can be defined as the moving of soil particles closer together by external forces exerted by humans, animals, equipment, and/or the impact of water droplets. Packing the soil particles together results in the

Dual wheels and wide tires do not lessen compaction; only spread it out so that it does not go as deep. Photo: National Tillage Lab.



loss of pore space within the soil. This, in turn, leads to poorer internal drainage and aeration.

Under many soil conditions compaction leads to slower water infiltration, which results in greater runoff and soil loss from both rainfall and irrigation.

Compaction effects on the crop include reduced plant growth, especially root development, decreased crop yield, and delayed maturity.

Measuring compaction

There are two methods commonly used by researchers to measure the magnitude of soil compaction. One is soil bulk density, the other is taken with a soil penetrometer.

Bulk density is simply the dry weight of a known volume of soil. Often it is reported in terms of grams per cubic centimeter (g/cm^3). It is easy to see that a particular volume of soil (whether a cubic centimeter or whatever) will weigh less if it contains a great deal of air and more if it contain little air.

Bulk densities of clay soils normally range from 1.2 to 1.5 g/cm^3. Sandy soils range from 1.6 to 1.8 g/m^3.

The cone penetrometer index (or simply cone index) is an indirect measurement. Researchers measure the amount of force it takes to push a rod with a cone-shaped point through the soil. These measurements are generally reported in pounds per square inch (psi).

This type of measurement is not unlike judging the compaction of a soil by noting how much force it takes to push a spade or soil sampling probe into it.

A version of the penetrometer—the needle penetrometer—is smaller in diameter than the standard cone and sometimes used to evaluate the actual resistance a root would encounter in the soil.

Research from Georgia has shown that, when the soil moisture is near field capacity, penetrometer values greater than 200 psi reduce root growth and values greater than 300 psi frequently reduce crop yields.

The cone index is a function of both soil strength and soil moisture content. Different soil textures have different strengths, just as they have different weights per given volume. The strength of a soil at a given time depends on both compaction and moisture content.

For a given soil moisture content and soil type, a larger cone index number means more compaction. The cone penetrometer is useful for comparing the magnitude of compaction on adjacent plots that have similar soils and moisture contents.

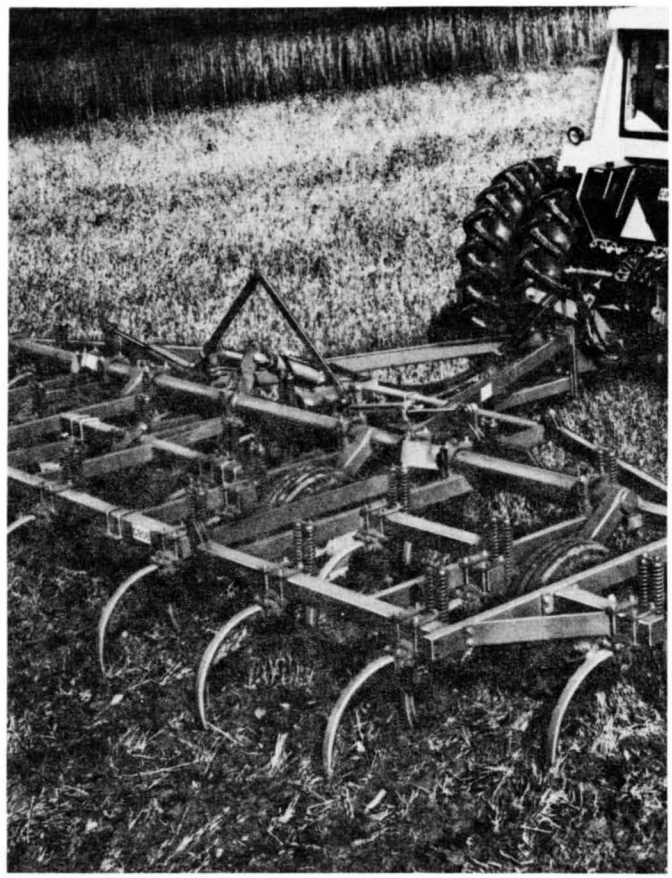
Cone index measurements among different locations are not as valid, because of differences among soil types, moisture content, and the degree of compaction.

Effect on yield

Soil compaction may be beneficial in some circumstances. As an example, press wheels on seeding equipment are generally designed to firm loose soil around the seed to provide the needed seed-to-soil contact for germination. This is soil compaction but the magnitude of compaction is slight when compared to that created by driving on or tilling a soil which is too wet.

Studies in Iowa showed that compaction could reduce corn yields 10 percent. Research in Indiana showed a reduction in corn yields of up to 50 percent in soils that were both compacted and had excess water, and 45 percent in compacted soils with a more normal water regime. Moderate subsoil compaction reduced yields by 25 percent.

Similar yield reductions have occurred elsewhere. Most experts say the yield reductions are brought about because compaction reduced the depth and proliferation of roots and slowed overall plant growth.



Fall tillage can either lessen or increase soil compaction, depending on soil conditions when it is done. Photo: J. I. Case Co.

Even relatively low levels of compaction will slow root elongation.

Minnesota research showed that compaction caused by wheel traffic reduced or eliminated root growth in 60 percent of the upper 12 inches of a clay loam soil. Since most fertilizer is incorporated in this layer, it means that plant uptake of immobile fertilizer elements, such as phosphorus, may be reduced.

Another test in Minnesota compacted soil by running equipment across it that weighed 20 tons per axle. Yields of soybeans were still reduced 14 percent 2 years after the

Corn yields are influenced both by the amount of compaction and the soil type. (Information from Pope in Illinois, 1982.)

	Soil	
Treatment	Silty Clay Loam Poorly Drained	Silt Loam Somewhat Poorly Drained
Control		
Plow, Disk, Disk, Plant	124	106
Moderate Compaction		
Pack, Plow, Disk, Disk, Plant	116	104
Plow, Disk, Disk, Plant, Pack	109	100
Severe Compaction		
Pack, Pack & Plow, Disk, Disk, Plant	111	108

A combine with a full grain tank can weigh as much as 20 tons per axle; a tremendous force for compaction if you use it when soil conditions are not right. Photo: New Holland.

compaction occurred. Corn yields were reduced 25 percent the first year after the compaction and 15 percent the second year.

In Wisconsin, a loaded combine that weighed about 14 tons was used on wet soil and caused a corn yield loss of 14 bushels per acre the following season. Also, a liquid manure tank weighing about 14 tons, pulled by a 9-ton tractor, caused a 52 bushel per acre loss on a silt loam soil underlain with a heavy clay subsoil.

Work in Illinois studied the effects of severe compaction on two soil types. One was Thorp silt loam, a somewhat poorly drained soil with about 4 percent organic matter. The other was Drummer silty clay loam, a poorly drained soil with about 6 percent organic matter.

With the soil moisture content near field capacity, both of these soils were subjected to various tillage and compaction treatments. The packing consisted of running the rear tractor tires across the entire plot twice. The pack and plow treatment made two passes with a one-bottom plow, then four passes with the rear tractor tire in the bottom of the furrow to ensure the formation of a plow pan.

Compaction reduced the yields on the finer textured, poorly drained soil, but not on the silt loam. As the table on page 13 shows the yields on the silt loam were poorer to begin with, though.

In Nebraska, a 4-year study assessed relationships among tillage, compaction, and moisture availability. The study was conducted on a poorly drained silt loam having a 2 percent slope.

Soil compaction, as indicated by cone index measurements, was highest for continuous no-till and lowest for moldboard plowing. The cone index generally increased as the amount of tillage decreased.

Corn yields also increased on the dryland plots as the tillage increased. The no-till had the lowest yield; the moldboard plowed plot had the highest yield.

With irrigation, however, there were no significant yield advantages for any tillage system, even though the no-till plots still had the highest cone index.

This research implies that a reduction in root growth due to compaction may not cause a yield reduction if the plant is not stressed for water or nutrients. Thus, compaction created by tillage may or may not affect yield, depending on the location of the roots and the availability of water and nutrients at that location.

Even though compaction may limit root development, timely rainfall or irrigation reduces the possibility of yield decreases. The study also showed that large cone index measurements (compaction) will reduce yields.■

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