

Understanding & Managing Soil Compaction



Conservation Quiz

- 1. How does soil compaction affect soil moisture?*
- 2. How can you determine that you have soil compaction?*
- 3. What is the cost of soil compaction?*

(Answers located on page 3.)

Soil compaction occurs when soil aggregates and particles are compressed into a smaller volume. As soil is compacted, the amount of open pore, or void space, decreases and the density, or weight of the soil per unit volume, increases measurably. Soil density increases naturally with depth. Soil below the surface is naturally more dense than the surface layer because it supports the weight of overlying material. Excessively compacted soil results in problems such as poor root penetration, reduced internal soil drainage, reduced rainfall infiltration, and lack of soil aeration from larger macropores.



Table 1: Sample implement weights

Implement	Weight (tons/axle)
Combine w/250 bu. grain, front axle	18
Grain cart w/875 bu. grain, single axle	23
Large manure tank, filled	17
Tractor (175 hp, 2 wheel-drive), rear axle	8

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Effects of Equipment on Compaction

Although compaction can occur from hooves of livestock, most compaction in agricultural soils results from field traffic of farm machinery. Modern farming systems require the steel frames of planting, chemical application, and harvesting equipment to be supported by the soil.

As the size of farms has increased, so has the size and weight of farm equipment. Public right-of-way regulations require axle loads to be no greater than 20,000 pounds for most vehicles. The front axle load of a large combine with attached head and full grain tank, or the axle load of a full grain cart or liquid manure tank, may exceed this value by 50 percent or more.

An example of the great mass of some agricultural vehicles occurred in Iowa a few years ago when a locomotive struck a large (filled) manure tanker at a railroad crossing and the locomotive was derailed. It can be argued that our public roadways receive lighter compactive loads than our agricultural soils.

Soils are compacted more readily when soil moisture is at or near field capacity. Road builders make use of this principle when they apply water to dry soil to make it compact more easily. When soil pores, or voids, are filled with roughly equal amounts of air and water (near field capacity), aggregates are lubricated by water and can re-position themselves through air spaces. One common management strategy to prevent compaction is to avoid field operations if possible when soils are in this stage of moisture. This usually occurs on the first day a tractor can be operated in the field after a rain without getting stuck.

Effects of Compaction on Soil's Physical Properties

The major impact of soil compaction is the alteration of soil's physical properties. The most notable changes are in soil bulk density, soil strength, porosity, and hydraulic properties such as infiltration rate and hydraulic conductivity. These changes affect the water and air movement through the soil. The right proportions of air and water are critical to providing a healthy root system soil environment.

The ratio of solids to water and air is a function of soil texture. For example, medium fine texture soils (i.e., loam) consist of approximately 50 percent solids and 50 percent void space (air and water). When soil is compacted due to implement traffic (tillage, manure or fertilizer application, etc.) the major change will be in soil bulk density, in which the amount of void space is reduced — and ultimately soil bulk density itself — is increased. When this change occurs, the total porosity is reduced due to the compaction of soil particles, which leads to reduction in the space that the water and air can occupy. The reduction in pore space not only occurs in total but also in size — large pores are reduced in size, restricting water and air movement. The large pores are generally responsible for water and air movement within the soil system. Because larger pores are often filled with air rather than water, a reduction in pore sizes may lessen the ability of roots to obtain oxygen from the air above.

The impact of compaction on soil's physical properties, and mainly water movement, is evident through the reduction of soil hydraulic properties such as infiltration. Infiltration is the penetration of water into the soil. It is measured as depth of water per unit of time (i.e., inch/hour), which is called infiltration rate. The reduction of this infiltration rate has a serious consequence to water quality and sediment transport, particularly on sloping soils. Compaction can contribute to earlier and larger volumes of surface runoff and major soil loss due to water erosion. Compaction also can increase chemical runoff losses. Iowa State University research found atrazine losses in surface runoff were three

times greater in compacted areas from tractor traffic than in adjacent uncompacted areas. The increase in soil compaction on relatively flat fields can create significant internal drainage problems where water stands on the soil surface. This creates a serious soil production condition, reduces water availability at lower depths, and restricts root penetration in the soil profile.

The change in soil density or strength is a significant problem for plant growth as well as for the efficiency of tillage equipment. Highly compacted soils require more horsepower, and tillage and planting equipment may not function properly.

Effects of Compaction on Yield and Crop Residue

For producers, the main concern about soil compaction is its impact on yields and soil productivity. Reduction in grain yield also means reduction in dry matter production and ultimately, the amount of crop residue left on the soil surface after harvest. The poor plant growth caused by compaction is due to the negative impact on soil moisture and air availability to the root system. It has been reported that compacted fields may experience yield losses of 10 to 20 percent in some years. The impact of compaction on yield and residue cover may not be observed some years, when favorable growth conditions such as moisture availability, timing of high rainfall, and fertilizer use can mask its effects for that particular growing season. On the other hand, if the good growing conditions exist but plant productivity is not great, there is a need to investigate soil compaction as a potential culprit.

In a four-year continuous corn study on alluvial soil in southeast Iowa, corn grown on soil farmed with equipment exerting a maximum 6 psi surface pressure yielded 9 bushels per acre more than corn grown using more conventional equipment with 16 psi surface pressure. Much of the effect may result from plants seeded into that spring's traffic tracks. In an earlier study on the same soil, corn yield was depressed 27 and 18 bushels per acre, respectively, for plants growing in higher-pressure wheel-type tracks and lower-pressure track-type tracks, as compared to plants growing in adjacent soil outside the tracks (untracked areas). (See Table 2.) Not all soils may exhibit this much yield depression, however. Research data in Iowa and the Midwest indicate that if traffic and compaction are allowed to occur on wet soils and soil aeration is limited, yields over time may be reduced by 4 to 6 bushels per acre for corn and by 2 to 3 bushels per acre for soybeans.

Management Strategies to Reduce Soil Compaction

If possible, avoid operating equipment on soil when it is too wet. For example, if fall rains have replenished soil moisture and it's not too late in the harvest season, avoid driving a loaded grain cart randomly throughout the field. If cart traffic is unavoidable, use



controlled traffic lanes for the cart because most compaction damage occurs in the first pass or two of the implement. If soil is dry or frozen, grain cart or loaded combine traffic may not cause much compaction. Further, winter freeze-thaw cycles may reduce or reverse the damage.

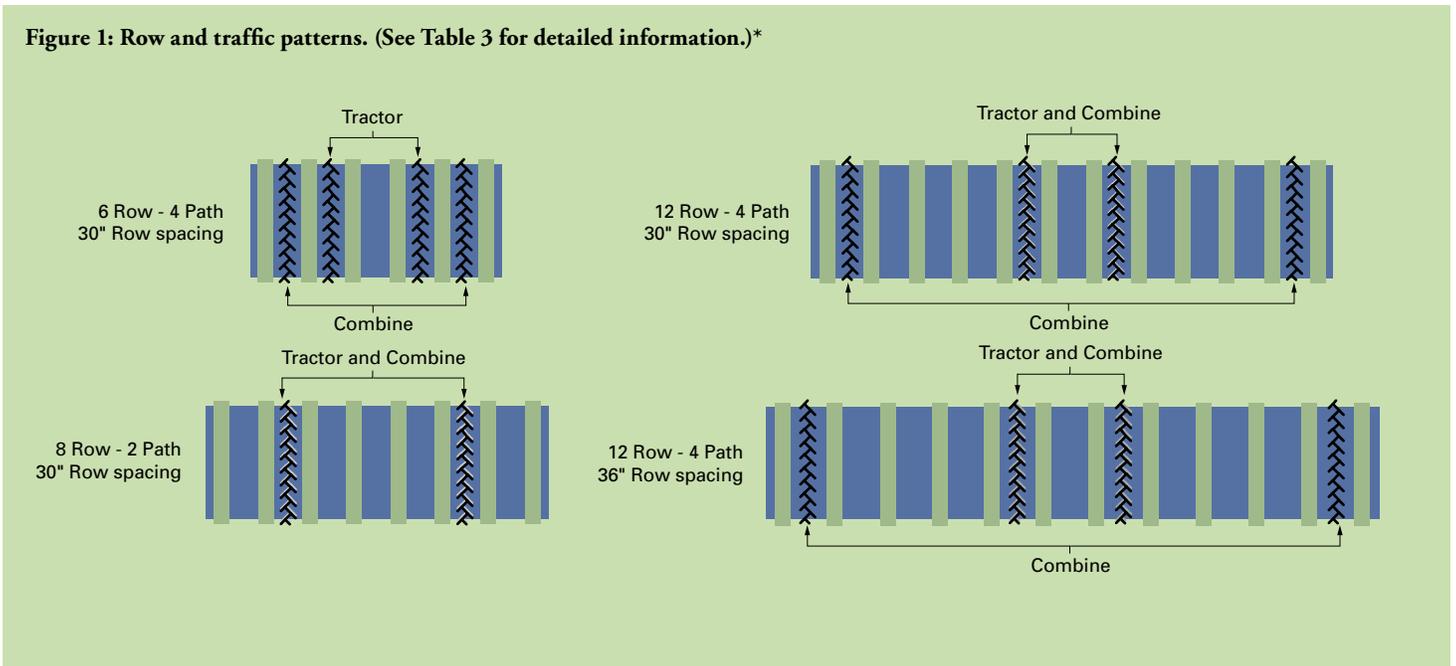
Table 2: Tractor track effect on corn growth¹

Location	Pop/a	Yield, bu/a	Grain Moisture at Harvest, %
Tractor tracks (wheel- and track-type)	22,700	143	20.9
Untracked area	23,500	166	20.6
Wheel-type track (high pressure)	22,200	139	21.0
Track-type track (low pressure)	23,600	148	20.8

¹4 year average, '84 - '87, Chequest silty clay loam, Wever, IA, Continuous corn (Erbach et al., 1988)

Quiz Answers: 1. Soil compaction reduces infiltration, thus reducing water recharge to lower depths. 2. Inspect the field by digging roots, pushing rods, or using a shovel. 3. Yields may be reduced by several bushels per acre and more horsepower and fuel are required for tillage.

Figure 1: Row and traffic patterns. (See Table 3 for detailed information.)*



*Adapted and modified from “Conservation Tillage Systems and Management,” MWPS-45, Page 79, 2nd Ed., 2000.)

Using the same wheel tracks (controlled traffic) helps to minimize the amount of land area damaged by compaction. In addition, building soil strength into designated tracked paths helps to support the weight of field equipment. (See Figure 1 and Table 3.)

Research indicates that high surface contact pressure, such as from over-inflated tires, concentrates loads onto smaller areas and compacts soil. Using larger wheels and tires for floatation of a given load allows lower inflation pressures. Although less conclusive, research also suggests that large axle loads (greater than 10,000 to 15,000 pounds) may cause some compaction in subsoil, even if surface pressure is relatively light (e.g., 10 to 15 psi).

Table 3: Sample traffic patterns¹

Sample wheel spacings for tractor and combine, single and dual tire options. Percent of the field trafficked assumes each path is 20” wide.

No. of rows	Tractor wheel spacing, inches	Combine wheel spacing, inches	No. of paths	% Trafficked
30” row spacing				
6	60	120	4	44
6	120	120	2	22
8	120	120	2	17
8	60 & 120	120 & 180	6	50
12	60 & 120	120 (6 row)	4	22
16	60 & 120	120 & 180 (8 row)	8	33
24	60 & 120	120 & 180 (12 row)	12	33
36” row spacing				
6	72	144	4	37
8	72	144	4	28
12	72	144 (6 row)	4	18

¹Adapted and modified from “Conservation Tillage Systems and Management,” MWPS-45, Page 78, 2nd Ed., 2000.)

Table 4: Maximum load (pounds) for selected radial tires used as duals at various inflation pressures (from tire manufacturer).

Tire Size	Inflation pressure, psi				
	6	8	10	12	14
18.4 R 38	2,640	3,100	3,485	3,875	4,225
18.4 R 46	2,905	3,400	3,875	4,350	4,720

Example of the advantage of larger wheel sizes:

A 275 hp, 4-wheel-drive (4WD) tractor is outfitted with duals on the front and rear axles. When properly ballasted for a drawbar load, its gross vehicle weight of 24,750 pounds is divided into 13,610 pounds (55 percent) on the front-axle and 11,140 pounds (45 percent) on the rear-axle.

Spreading loads across all four wheels on each axle, wheels on the front axle will each carry 3,403 pounds and wheels on the rear axle will each carry 2,785 pounds. Using the load and inflation pressure for selected tire sizes (Table 4), tires on the front axle will need to be inflated to 10 psi if using 18.4R38 tires. If larger diameter wheel rims and 18.4R46 tires are selected, inflation pressure can be reduced to 8 psi. In a similar analysis, by using these larger tires on the rear axle, inflation pressure can be reduced from 8 to 6 psi.

If compaction is a concern, don't skimp on wheel sizes. Work with your implement and tire dealer to handle specific situations. Increasing the tire footprint area by increasing wheel diameter and thus lengthening the wheel print, rather than simply using wider tires, helps to avoid tracking additional soil area.

Measurements of Compaction

The first noticeable symptom of possible compaction is often stunted crop height. Because other agronomic problems can cause similar symptoms, additional measures of compaction should be made. Carefully dig up plants and examine rooting depth and structure to determine if compaction is causing the problem.

Water ponding caused by slower infiltration rates also may indicate compaction. Testing the mechanical strength of soil with a tile probe, spade, or penetrometer can indicate compaction, although dry soil will have significant strength even if uncompacted. Because effects of compaction can be subtle, it's best to compare measurements with those made in an adjacent area that is not compacted (e.g., fence rows, adjacent fields with different field traffic). Because tillage to alleviate compaction costs \$7 to \$10 per acre, the problem should be confirmed before using resources to solve it.

Using Deep Tillage to Alleviate Compaction

Prior to deciding on using tillage to alleviate a soil compaction problem, think about the primary cause of the problem. Choosing different tillage practices and controlling traffic may alleviate the soil compaction. Conservation tillage practices and traffic management need to be the main strategies in avoiding soil compaction and improving yield. If conditions are dry enough to shatter soil between the points of a subsoiler or chisel plow, tillage can lower the bulk density of soil and reduce compaction. Soil at the compacted depth should not be wet and plastic, otherwise mechanical tillage will do little to loosen soil. Till only to the depth needed to break up the compacted layer. Also evaluate field operations that may have caused the compaction and attempt to avoid them in the future. Otherwise, soil can be re-compacted to the depth of tillage. Also select the proper subsoiler shanks to achieve the desired mixing and residue cover.

To avoid compaction:

- *Inspect field for soil compaction.*
- *Don't drive on soil when moisture is at field capacity.*
- *Re-use the same wheel tracks (controlled traffic lanes).*
- *Use large diameter wheel rims and large tires to lower surface pressure by lengthening and spreading out the wheel print.*

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