Effects of Soil Compaction

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College of Agricultural Sciences
Agricultural Research and Cooperative Extension

Effects of Soil Compaction

INTRODUCTION

Soil compaction is the reduction of soil volume due to external factors; this reduction lowers soil productivity and environmental quality. The threat of soil compaction is greater today than in the past because of the dramatic increase in the size of farm equipment (Figure 1). Therefore, producers must pay more attention to soil compaction than they have in the past. In this fact sheet we will discuss the effects of soil compaction and briefly identify ways to avoid or alleviate it.

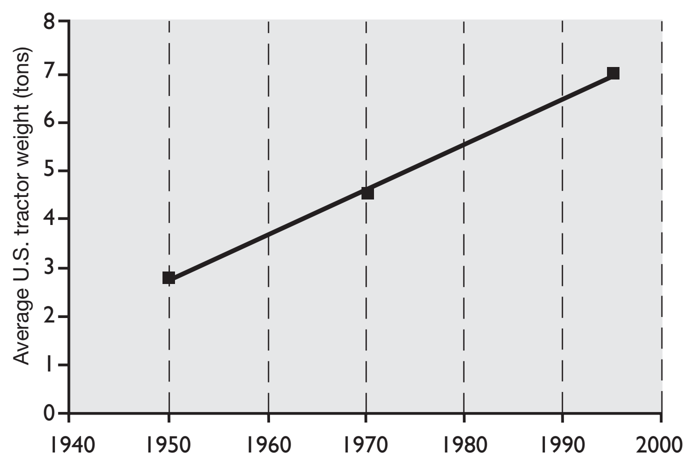


Figure 1. Tractor weight incresed dramatically since the 1950s.
Soane, B. D. and C. Van Ouwerkerk. 1998. "Soil compaction: A global threat to sustainable land use." *Advances in GeoEcology* 31:517–525.

EFFECTS OF COMPACTION ON CROP YIELDS

Soil Compaction Effects on Forages

The effect of traffic on alfalfa and grass sod is a combination of soil compaction and stand damage. In a recent study in Wisconsin and Iowa, annual alfalfa yield losses up to 37 percent due to normal field traffic were recorded. Based on this work, a multistate project was initiated to get a better understanding of yield losses due to traffic in alfalfa. Yield losses ranged from 1 to 34 percent (Figure 2). The damage to alfalfa stands is much greater 5 days after cutting than 2 days after cutting, showing the importance of timeliness in removing silage or hay from the field.

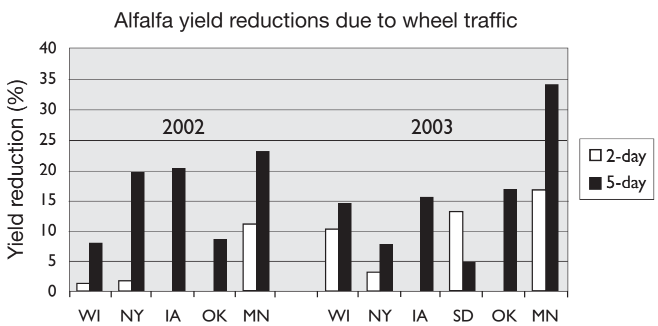


Figure 2. Yield losses due to traffic in alfalfa 2 and 5 days after cutting. One-hundred percent of the plots were wheeled six times with a 100-hp tractor.
Undersander, D. 2003. Personal communication.

Soil Compaction Effects on Tilled Soils

Tillage is often performed to remove ruts, and farmers assume that it takes care of soil compaction. Thus, farmers become careless and disregard soil moisture conditions for traffic and other important principles of soil compaction avoidance, assuming that they can always correct the problem with tillage.

Distinguishing between topsoil and subsoil compaction is important. Research has shown that tillage can alleviate effects of topsoil compaction on sandy soils in 1 year. However, on heavier soils more tillage passes and repeated freeze-dry cycles are required to alleviate effects of surface compaction. Therefore, the effects of topsoil compaction reduce yields on these soils despite tillage. Since most soils in Pennsylvania contain significant amounts of clay in their surface horizons, topsoil compaction is likely to reduce crop yields, even with tillage.

Subsoil compaction is below the depth of normal tillage operations. Research shows that subsoil compaction is not alleviated by freeze-thaw and wetting-drying cycles on any soil type. In an international research effort that included tillage after compaction, average first-year yield losses were approximately 15 percent, although results varied from year to year and from site to site (Figure 3). This first-year loss was considered to be primarily the result of topsoil compaction residual effects. Without recompaction, yield losses decreased to approximately 3 percent 10 years after the compaction event. The final yield loss, which was most likely due to subsoil compaction, can be considered permanent. The effects of subsoil compaction are due to using high axle loads (10 tons and heavier) on wet soil and are observed in all types of soils (including sandy soils).

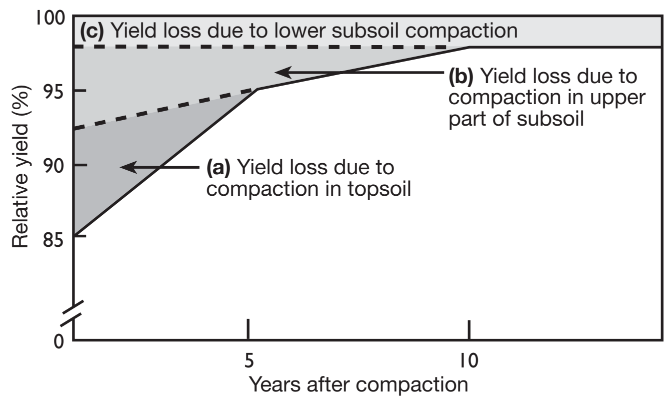


Figure 3. Relative crop yield on compacted soil compared to noncompacted soil with moldboard plowing. One-hundred percent of fields in multiple locations in northern latitudes were wheeled four times with 10-ton axle load, 40-psi inflated tires.
Hakansson, I. and R. C. Reeder. 1994. "Subsoil compaction by vehicles with high axle load—extent, persistence, and crop response." *Soil Tillage Research* 29:277–304.

Tillage can also cause the formation of a tillage pan. The most damaging form of tillage is moldboard plowing with one wheel (or horse) in the furrow, which causes direct subsoil compaction. On-land moldboard plowing is certainly preferred over this practice. However, even then the moldboard plow can still cause compaction just below the plow. The disk is another implement that can cause the formation of such a pan. In our research in Pennsylvania, we also observed the formation of plow pans on dairy farms that used the chisel plow (Figure 4, see next page).

More tillage operations and more power are needed to prepare a seedbed in compacted soil. This leads to increased pulverization of the soil and a general deterioration of soil structure, which makes the soil more sensitive to recompaction. Therefore, compaction can enforce a vicious tillage spiral that degrades soil (Figure 5) and results in increased emissions of the greenhouse gases carbon dioxide, methane, and nitrous oxide due to increased fuel consumption and slower water percolation. Ammonia losses also increase because of decreased infiltration in compacted soil. More runoff will cause increased erosion and nutrient and pesticide losses to surface waters. At the same time, reduced percolation through the soil profile restricts the potential for groundwater recharge from compacted soils. Thus, this vicious compaction/tillage spiral is an environmental threat with impacts beyond the individual field.

Soil Compaction Effects on No-Till Crop Production

No-till has a lot of advantages over tillage—reduced labor requirements, reduced equipment costs, less runoff and erosion, increased drought resistance of crops, and higher organic matter content and biological activity. The higher organic matter content and biological activity in no-till makes the soil more resilient to soil compaction. One study illustrates this very well (Figure 6). Topsoil from long-term no-till and conventional till fields were subject to a standard compaction treatment at different moisture contents. The "Proctor Density Test" is used to determine what the maximum compactability of soil is. The conventional till soil could be compacted to a maximum density of 1.65 g/cm^3, which is considered root limiting for this soil. The no-till soil could only be compacted to 1.40 g/cm^3, which is not considered root

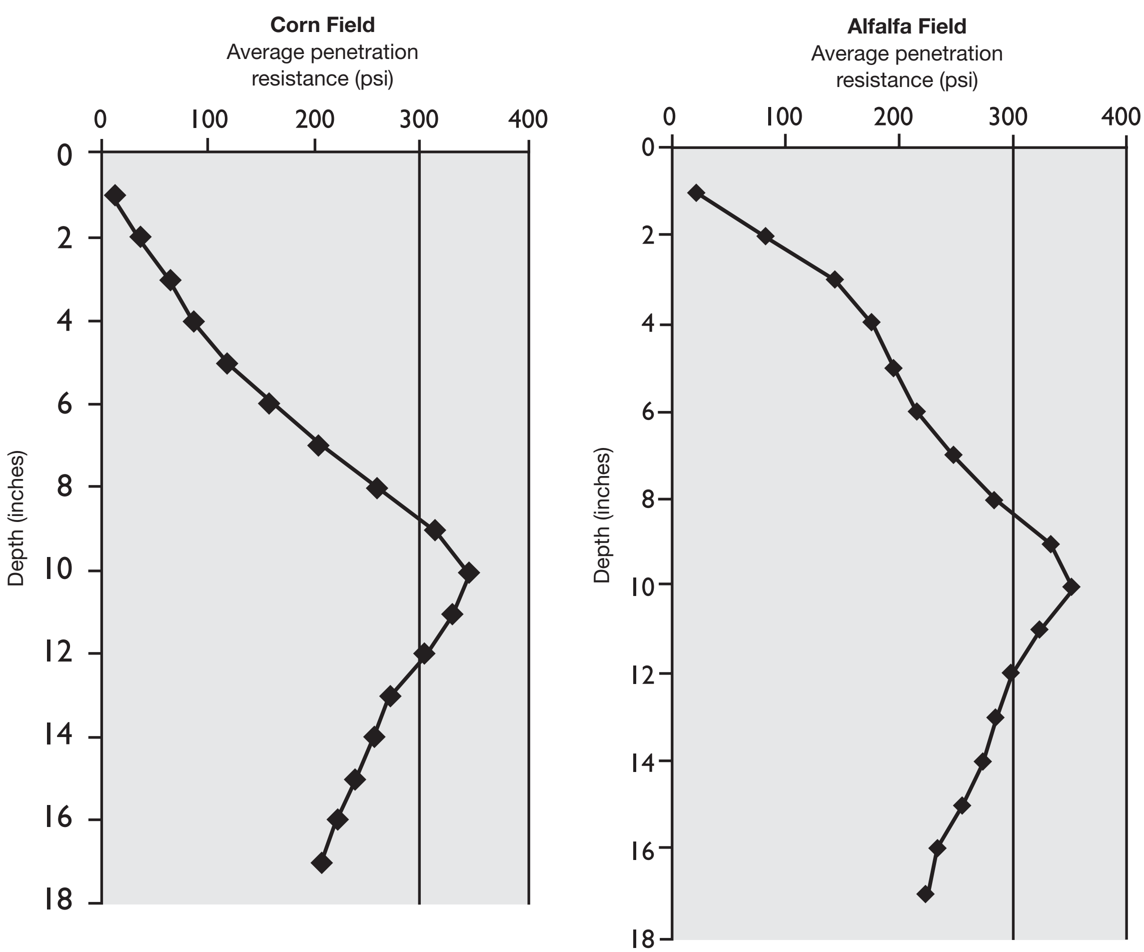


Figure 4. Penetration resistance on a PA dairy farm that used chisel/disking for field preparation. A pan was detected just below the depth of chisel plowing.

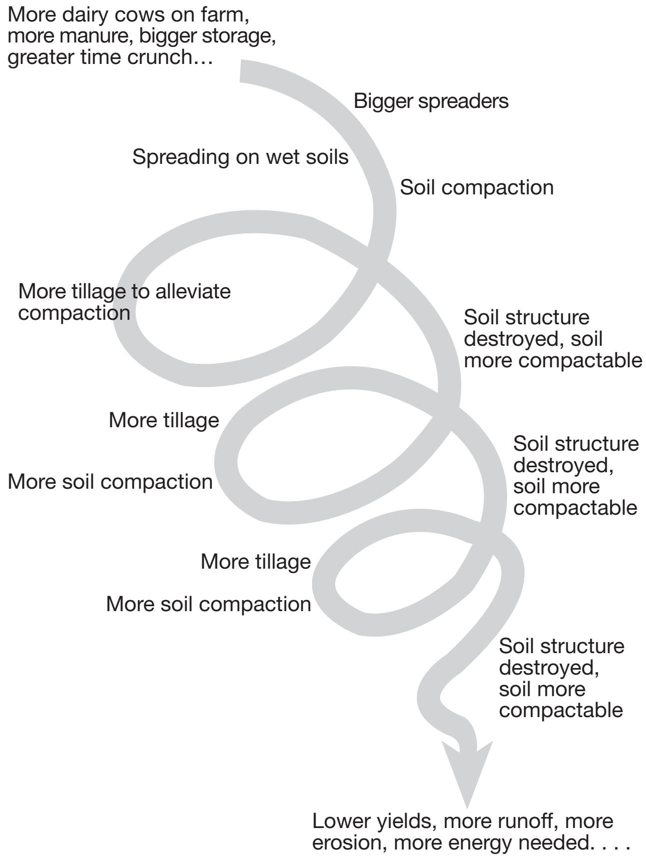


Figure 5. The dynamics of modern animal husbandry farms can easily lead to a downward compaction-tillage spiral of soil degradation.

limiting. Thus, topsoil compaction would be less of a concern in no-till fields. The increased firmness of no-till soils makes them more accessible, and no-till fields may become better drained over time.

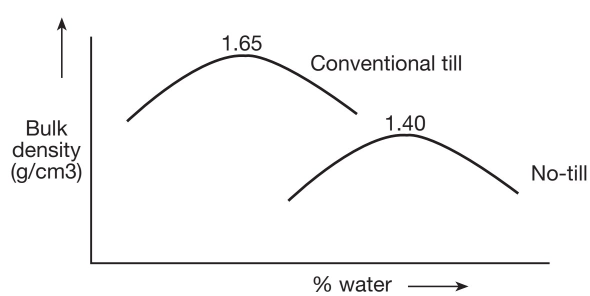


Figure 6. The surface of long-term, no-till soil cannot be compacted to as great a density as conventionally tilled soil due to higher organic matter contents.
Thomas, G. W., G. R. Haszler, and R. L. Blevins. 1996. "The effects of organic matter and tillage on maximum compactability of soils using the proctor test." *Soil Science* 161:502–508.

This being said, compaction can still have significant negative effects on the productivity of no-till soils. In our own research we observed a 30-bushel yield decrease in the dry year of 2002 and a 20-bushel yield loss in the wet year of 2003 (Figure 7). In research in Kentucky, corn yield on extremely compacted no-till soil was only 2 percent of that in uncompacted soil in the first year after compaction (Figure 8). Remarkably, the yields bounced back (without tillage) to 85 percent the second year after compaction and stabilized at approximately 93 percent after that. This shows the resilience of no-till soils due to biological factors, but it also shows that compaction can cause very significant short- and long-term yield losses in no-till.

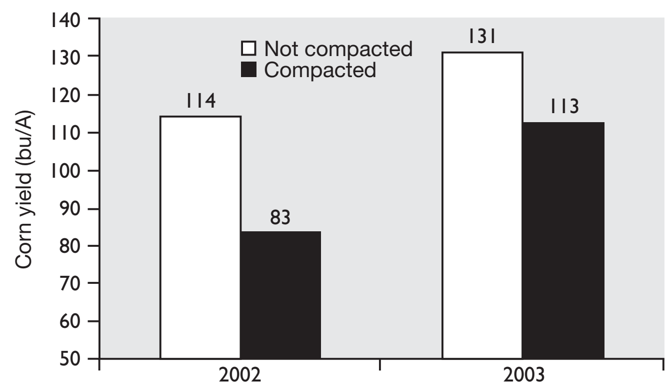


Figure 7. Soil compaction can result in significant yield losses in no-till. One-hundred percent of the field was compacted with a 30-ton manure truck with 100-psi inflated tires. (Penn State Trial in Centre County.)

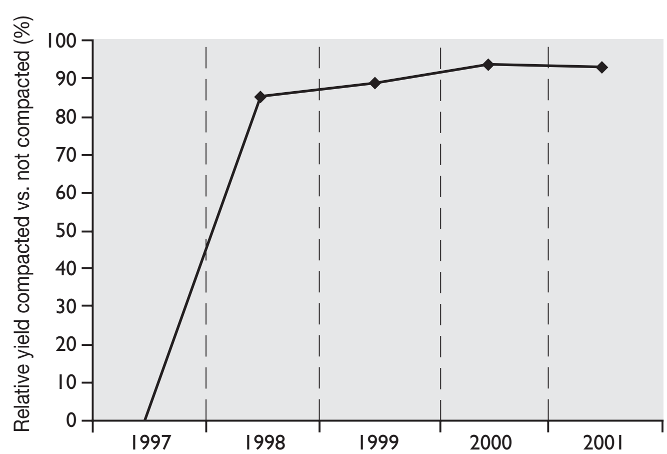


Figure 8. Corn yield reduction due to severe compaction in the top 12 inches of a long-term no-till soil in Kentucky.
Murdock, L. W. 2002. Personal communication.

EFFECTS OF SOIL COMPACTION ON SOIL AND CROP HEALTH

In this section we will review the effects of soil compaction on soil physical, chemical, and biological properties, as well as on crop growth and health.

Soil Density

The most direct effect of soil compaction is an increase in the bulk density of soil. Bulk density is the mass of oven-dry soil in a standard volume of soil, often given as grams per cubic centimeter (g/cm^3). Optimum bulk densities for soils depend on the soil texture (Table 1). Whenever the bulk density exceeds a certain level, root growth is restricted. A note of caution must be made here in respect to the effects of tillage on bulk density. No-till soils often have a higher bulk density than recently tilled soils. However, because of higher organic matter content in the topsoil and greater biological activity, the structure of a no-till soil may be more favorable for root growth than that of a cultivated soil, despite the higher bulk density.

Table 1. Ideal and root-restricting bulk densities.

Soil texture	Ideal bulk density	Bulk density restricts root growth
	g/cm^3	
Sand, loamy sand	< 1.60	> 1.80
Sandy loam, loam	< 1.40	> 1.80
Sandy clay loam, clay loam	< 1.40	> 1.75
Silt, silt loam	< 1.30	> 1.75
Silty clay loam	< 1.40	> 1.65
Sandy clay, silty clay	< 1.10	> 1.58
Clay	< 1.10	> 1.47

USDA. 1999. *Soil quality test kit guide.* USDA Soil Quality Institute. Washington, D.C.

Porosity

Due to the increase in bulk density, the porosity of soil decreases. Large pores (called macropores), essential for water and air movement in soil, are primarily affected by soil compaction. Research has suggested that most plant roots need more than 10 percent air-filled porosity to thrive. The number of days with adequate percentage of air-filled porosity will be reduced due to compaction, negatively affecting root growth and function. It is important to note that tilling compacted soils makes them more susceptible to recompaction. In one study, the total porosity and macroporosity of a pasture was compared to that of a plow pan in arable soil. In one case, the plow pan had never been broken up with subsoiling, whereas in the other case the plow pan had been broken up, but the pan had reformed after years of normal field traffic and tillage. The results illustrate the reduction of large pores in the plow pan and the worst condition of the recompacted plow pan (Figure 9). A long-term no-till soil that has not been subjected to compaction would be in a similar state as the pasture soil.

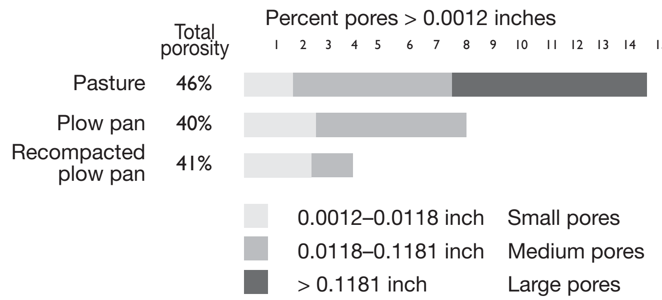


Figure 9. Total porosity and macroporosity were greatly reduced in an original and a subsoiled but subsequently recompacted plow pan compared to an uncompacted pasture
Adapted from Kooistra, M. J., and O. H. Boersma. 1994. "Subsoil compaction in Dutch marine sandy loams: Loosening practices and effects." *Soil Tillage Research* 29:237–247.

Penetration Resistance

Root penetration is limited if roots encounter much resistance. Research on completely disturbed soil packed to different densities has shown that root growth decreases linearly with penetration resistance starting at 100 psi until root growth completely stops at 300 psi (Figure 10). Penetration resistance is a better indicator of the effects of soil compaction on root

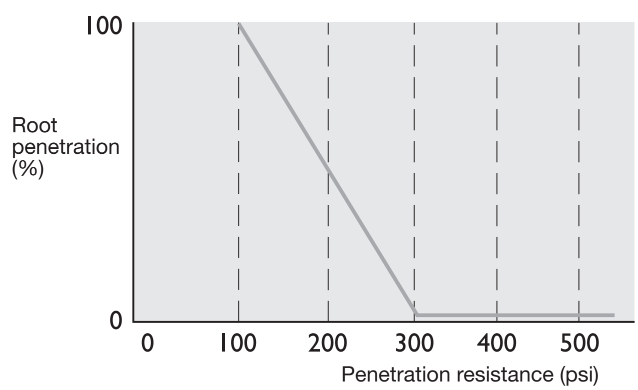


Figure 10. Relationship between penetration resistance and root penetration.
Adapted from Taylor, H. M., G. M. Roberson, and J. J. Parker. 1966. "Soil strength-root penetration relations for medium- to coarse-textured soil materials." *Soil Science* 102:18–22.

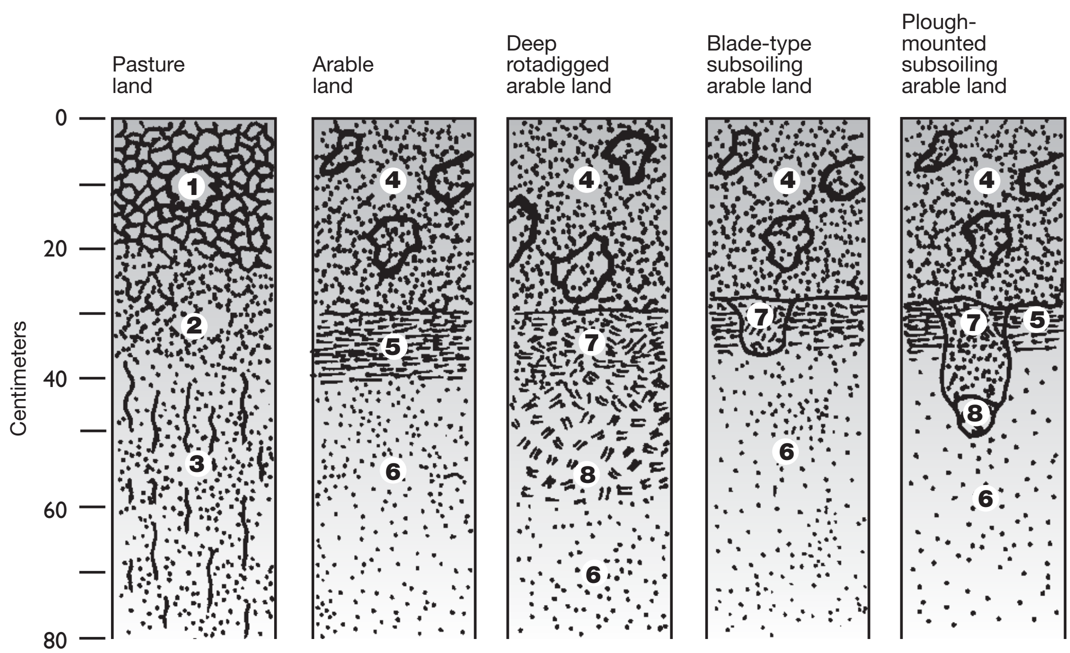
growth than bulk density because results can be interpreted independent of soil texture. More information on penetration resistance can be found in Agronomy Facts 63, *Diagnosing Soil Compaction Using a Penetrometer* (soil compaction tester), available from Penn State Cooperative Extension.

Soil Structure

Soil compaction destroys soil structure and leads to a more massive soil structure with fewer natural voids (Figure 11). In a pasture soil (similar to a no-till soil that has not been tilled for a long time), the soil structure is very well developed due to effects of increased organic matter and the fine root systems of grasses. Even if exposed to rainfall, such a soil will not wash away because the aggregates are very stable and infiltration is high. Pores can be seen below the topsoil because of the action of soil animals such as earthworms and roots. In tilled soil with plow pan, however, the structure of the topsoil is much weaker. Raindrops hitting the surface will quickly form a seal that becomes a crust upon drying. Infiltration will decrease rapidly on this soil. Below the depth of tillage a pan developed that is very dense, and below the depth of plowing few pores created by soil animals and decomposed roots are visible. Subsoiling the plow pan helps, but it does not improve soil structure (Figure 11). To improve soil structure, stimulating soil biological activity by reducing tillage and increasing the inputs of organic matter is necessary.

Soil Biota

Soil contains a tremendous number of organisms. They can be classified into micro- , meso- , and macrofauna (small, medium, and large sized). Bacteria and fungi are important microfauna in soil that live on organic matter or on living plants. An acre of grassland contains 0.5–1 ton of bacteria and 1–2 tons of fungi biomass. The same soil contains approximately 10 tons of living grass roots and 40 tons of "dead" organic matter. Most bacteria and fungi perform useful functions such as the decomposition of plant residues, release of nutrients, and formation of aggregates. Some bacteria such as rhizobia provide nitrogen to plants. Some fungi live in symbiosis with plant roots, facilitating the uptake of immobile nutrients such as phosphorus and potassium. Only few bacteria and fungi have negative effects (e.g., plant diseases).



1. Strongly developed structure, crumb
2. Weakly developed structure, crumb
3. Soil material with many old root and earthworm channels
4. Weakly developed structure, cloddy
5. Plow pan, compacted, few root or earthworm channels
6. Soil material with root channels
7. Broken plow pan with some large air pockets
8. Weakly developed structure

Figure 11. Soil compaction damages soil structure, and tillage does little to improve it.
Adapted from Kooistra, M. J., and O. H. Boersma. 1994. "Subsoil compaction in Dutch marine sandy loams: Loosening practices and effects." *Soil Tillage Research* 29:237–247.

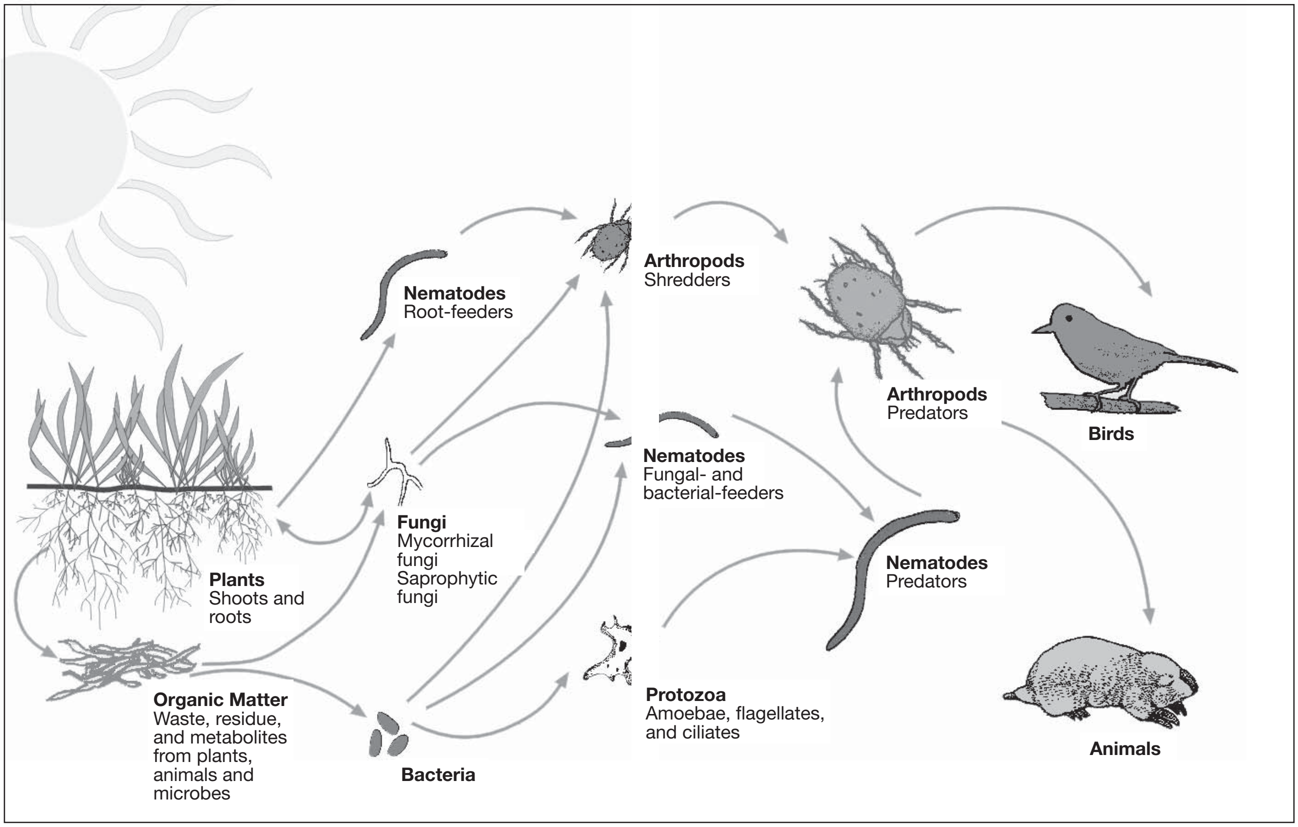


Figure 12. The soil food web. Courtesy USDA Natural Resources Conservation Service.

Bacteria and fungi are at the bottom of the soil food web (Figure 12). They are fed upon by other organisms such as protozoa, nematodes, and arthropods (some nematodes feed on plant roots), which are fed on by bigger soil animals. Having a greater diversity of soil organisms helps keep the "bad" bugs under control because predators may also be numerous.

Soil compaction affects the habitat of soil organisms by reducing pore size and changing the physical soil environment. The smallest organisms such as bacteria and fungi can live in pores that are not easily compacted. Even protozoa are very small and are not likely to be affected directly by compaction. Nematodes, on the other hand, will most likely be reduced in number by soil compaction because their pore space might be reduced. This could affect both the "bad" (root-feeding) and the "good" (fungal- and bacterial-feeding) nematodes. Because compaction can reduce the population of fungal- and bacterial-feeding nematodes, it is feasible that the bacterial population increases with compaction because there are fewer predators.

Another effect of compaction on soil biota is indirect. Due to slower percolation of water in compacted soil, prolonged periods of saturated conditions can occur. Certain soil organisms then start to use nitrate instead of oxygen, and denitrification occurs. Certain anaerobic bacteria release hydrogen sulfide (rotten egg–smell typical of swamps). This gas is toxic to many plants. In general, organic matter decomposition will be slower in compacted soils, and less biological activity will occur.

Larger soil animals (meso- and macrofauna) are also affected by soil compaction. Nonburrowing animals such as mites, springtails, and fly larvae will have an especially difficult time living in compacted soil. Burrowing animals such as earthworms, termites, ants, and beetles can defend themselves better but will still suffer negative effects. In a study in Australia, compaction of wet soil with a 10-ton axle load decreased total macrofauna numbers. Earthworms decreased from 166,000 to 8,000 per acre due to severe compaction (Table 2). Compaction of dry soil with 6-ton axle load did not have a negative effect on macrofauna. Earthworm tunnel creation was reduced in soils with high bulk density, indicating reduced earthworm activity (Figure 13).

Soil organisms are extremely important for soil productivity and environmental functions, especially in no-till. Therefore, the reduction of biological activity due to compaction is of great concern. Fortunately,

Table 2. Effects of soil compaction on earthworm counts in Australia (average of 5 years).

Compaction treatment	Earthworms (# per acre)
No compaction	166,000
Annual compaction of wet soil @ 10-ton axle load	8,000
Annual compaction of wet soil @ 6-ton axle load	20,000
Annual compaction of dry soil @ 6-ton axle load	220,000
Compaction only in first year	110,000
Deep tillage after compaction in first year	100,000

Adapted from Radford, B. J., A. C. Wilson-Rummenie, G. B. Simpson, K. L. Bell, and M. A. Ferguson. 2001. "Compacted soil affects soil macrofauna populations in a semi-arid environment in central Queensland." *Soil Biology & Biochemistry* 33:1, 869–1, 872.

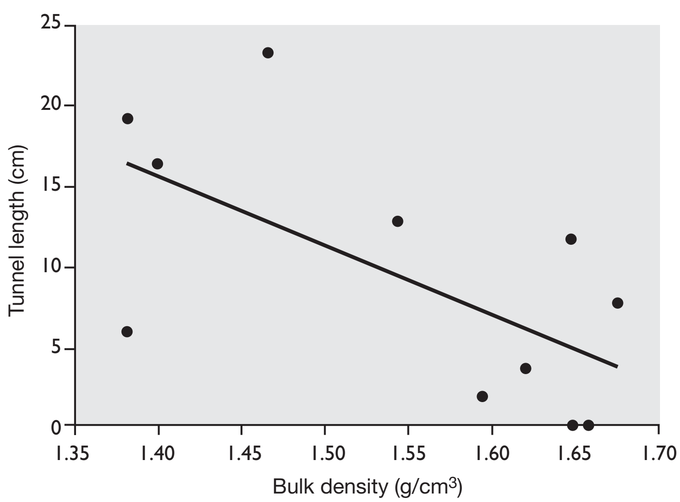


Figure 13. Soil compaction reduces earthworm tunneling. Rushton, S. P. 1986. "The effects of soil compaction on *Lumbricus terrestris* and its possible implications for populations on land reclaimed from open-cast coal mining." *Pedologie* 29:85–90.

higher biological activity in no-till soils also helps them recover from compaction more quickly than tilled soils. To guarantee high soil productivity, however, avoiding soil compaction is necessary.

Water Infiltration and Percolation

Soil compaction causes a decrease in large pores (called macropores), resulting in a much lower water infiltration rate into soil, as well as a decrease in saturated hydraulic conductivity. Saturated hydraulic conductivity is the movement of water through soil when the soil is totally saturated with water. Unsaturated hydraulic conductivity is the movement of water in soil that is not saturated. Unsaturated hydraulic conductivity sometimes increases due to compaction. Unsaturated hydraulic conductivity is important when water has to move to roots. Thus, compacted soils are sometimes not as drought sensitive as uncompacted soils—assuming the root system is of equal size in both cases, which is usually not the case. Typically, the net effect of compaction is that crops become more easily damaged by drought because of a small root system.

In an experiment on grassland, the macropore volume of compacted soil was half that of uncompacted soil (Table 3). The air permeability and infiltration rate were reduced dramatically. Reduced aeration and increased runoff will be the result.

Table 3. Effects of compaction on macropore volume, air permeability, and infiltration rate in a grassland study.

Compaction treatment	Macropore volume (ft^3/ft^3)	Air permeability (mm^2)	Infiltration rate (inch/hr)
Uncompacted	0.119	55	1.06
Compacted	0.044	1	0.25

Douglas, J. T. and C. E. Crawford. 1993. "The responses of a ryegrass sward to wheel traffic and applied nitrogen." *Grass Forage Science* 48:91–100.

If a soil is tilled after compaction, the infiltration rate will be high because the soil is cloddy and rough. Seedbed preparation to shatter clods includes several passes with a tractor over the field. This will decrease surface roughness, but compacted soil that has been tilled has coarser aggregates than the same soil that was not compacted. So, the infiltration rate may still be rather high in the compacted soil immediately after tillage. The action of raindrops on the soil surface and subsequent trips over the field destroy much of this apparent advantage. This is visible in the field as stagnating water in wheel tracks (Figure 14, see next page). It is common for runoff and erosion to start in these wheel tracks, especially if they run up and down the slopes.

Root Growth

Root growth in compacted soils is restricted because roots can develop a maximum pressure above which they are not able to expand in soils. As mentioned above, the maximum penetration resistance (measured with a standard conepenetrometer) that roots can overcome is 300 psi. In many cases, cracks and fissures will be available for roots to grow through, so a total

Figure 14. Soil compaction causes reduced infiltration.

lack of root growth is not likely. Instead, roots will concentrate in areas above or beside compacted zones in the soil (Figure 15). Aside from the effect of penetration resistance, roots also suffer from increased anaerobic conditions in compacted soils. A reduction of root growth will limit root functions such as crop anchoring and water and nutrient uptake. In addition, soil compaction has been found to reduce nodulation of leguminous crops such as soybean, which may limit nitrogen nutrition of these crops.

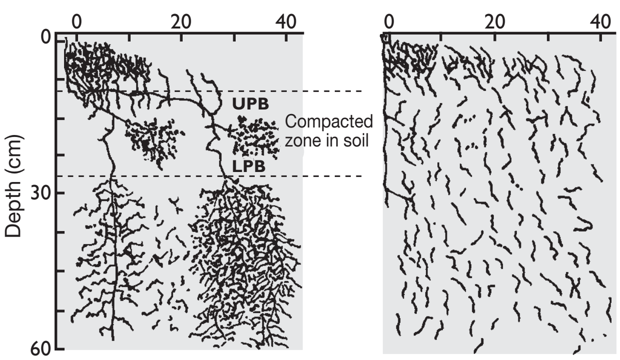


Figure 15. Roots occupy a larger soil volume in uncompacted soil (left) than in compacted soil (right).
Adapted from Keisling, T. C., J. T. Batchelor, and O. A. Porter. 1995. "Soybean root morphology in soils with and without tillage pans in the lower Mississippi River valley." *Journal of Plant Nutrition* 18:373–384.

Nutrient Uptake

Soil compaction affects nutrient uptake. Nitrogen is affected in a number of ways by compaction: (1) poorer internal drainage of the soil will cause more dentrification losses and less mineralization of organic nitrogen; (2) nitrate losses by leaching will decrease; (3) loss of organic nitrogen (in organic matter) and surface-applied nitrogen fertilizer may increase; and (4) diffusion of nitrate and ammonium to the plant roots will be slower in compacted soils that are wet, but faster in those that are dry. In humid temperate climates— as in Pennsylvania—soil compaction primarily increases denitrification loss and reduces nitrogen mineralization. In one study on a loamy sand in a humid temperate climate, nitrogen mineralization was reduced 33 percent and the denitrification rate increased 20 percent in a wet year. In a study with ryegrass, the nitrogen rate had to be more than doubled on the compacted soil to achieve the same dry matter yield (Figure 16). Thus, compaction results in less-efficient use of nitrogen and the need to apply more for the same yield potential.

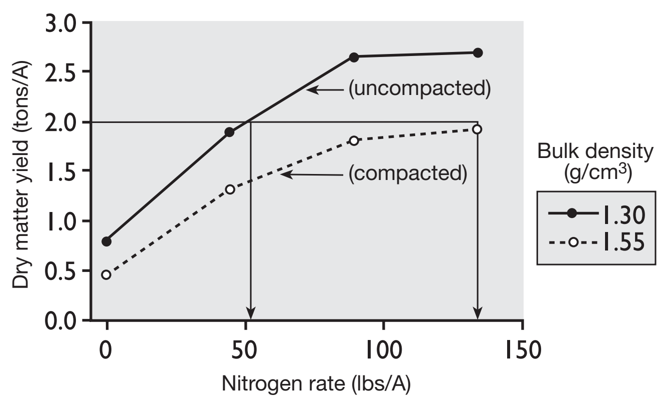


Figure 16. Nitrogren response curve of ryegrass on a clay loam soil in Scotland in compacted and uncompacted soil. To achieve the same yield of 2 tons/acre more than twice the amount of nitrogen had to be applied.
Douglas, J. T., and C. E. Crawford. 1993. "The responses of a ryegrass sward to wheel traffic and applied nitrogen." *Grass Forage Science* 48:91–100.

Compaction strongly affects phosphorus uptake because phosphorus is very immobile in soil. Extensive root systems are necessary to enable phosphorus uptake. Because compaction reduces root growth, phosphorus uptake is inhibited in compacted soil (Figure 17). Potassium uptake will be affected in much the same way as phosphorus.

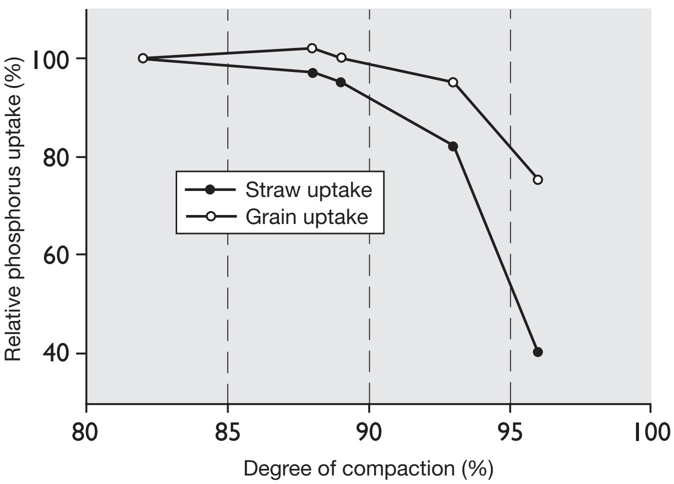


Figure 17. Phosphorus uptake and concentration in grain and straw are decreased due to soil compaction.
Lipiec, J., and W. Stepniewski. 1995. "Effects of soil compaction and tillage systems on uptake and losses of nutrients." *Soil Tillage Research* 35:37–52.

MANAGING SOIL COMPACTION

The primary aim of this fact sheet has been to review effects of soil compaction on soil properties and crop growth. Soil compaction increases soil density, reduces porosity (especially macroporosity), and leads to increased penetration resistance and a degradation of soil structure. This degradation is enforced when tillage is used to break up compacted soils. Soil biota suffers from compaction. For example, earthworm numbers and activity will be reduced in compacted soils; water infiltration and percolation are slower in compacted soils; root growth will be inhibited due to soil compaction, leading to reduced uptake of immobile nutrients such as phosphorus and potassium; and increased nitrogen losses can be expected because of prolonged periods of saturated conditions in compacted soils. Thus, limiting soil compaction is necessary. Below are some tips to manage compaction. More information is available in the fact sheet *Avoiding Soil Compaction*, which is available from Penn State Cooperative Extension.

- **Avoid trafficking wet soil.** Only wet soil can be compacted. Fields should not be trafficked if they are at or wetter than the plastic limit. To check if soil is at the plastic limit, start by taking a handful of soil. If you can easily make a ball by kneading this soil, conditions are suboptimal for field traffic. Artificial drainage can help increase the number of trafficable days on poorly drained soil.
- **Keep axle loads below 10 tons.** Subsoil compaction is caused by axle load and is basically permanent. To avoid subsoil compaction, keep axle loads below 10 tons per axle—preferably below 6 tons per axle.
- **Decrease contact pressure by using flotation tires, doubles, or tracks.** Topsoil compaction is caused by high contact pressure. To reduce contact pressure, a load needs to be spread out over a larger area. This can be done by reducing inflation pressure. A rule of thumb is that tire pressure is the same as contact pressure. Tires inflated to 100 psi such as truck road tires should be kept out of the field. To be able to carry a load at low inflation pressure, bigger or multiple tires are needed, hence the need for flotation tires and doubles. Large-diameter tires also help to increase the tire footprint. Tracks help to spread the load over a large area, but having multiple axles under the tracks is necessary to avoid high spikes of pressure. Tracks have the advantage over doubles of reducing contact pressure without increasing the area of the field trafficked.

- **Decrease trafficked area by increasing swath and vehicle width or by decreasing number of trips.** Reduce the area of a field that is subject to traffic by increasing swath width of manure spreaders or the spacing between wheels so individual wheel tracks are more widely spaced. Using larger equipment and no-tillage can reduce the number of trips across the field. A very promising approach is to use permanent traffic lanes and never traffic the area between the lanes with heavy equipment. The disadvantage of such an approach is the need to adjust wheel spacing on all heavy equipment.
- **Increase soil organic matter content and soil life.** Soil that has high organic matter content and thrives with soil organisms is more resistant to compaction and can better recuperate from slight compaction damage. To increase organic matter content, return crop residue to the soil, grow cover crops in the off season, and use compost and manure. Manage for maximum productivity to optimize organic matter input in the soil. Reduce losses of organic matter by preventing soil erosion and using no-tillage. These practices will also help increase biological activity in soil.
- **Use tillage sparingly.** Soil tillage should be used sparingly to alleviate compaction when no other means can be used. Growers should avoid falling into the vicious compaction/tillage spiral as explained earlier. If any tillage is done, try to leave as much crop residue as possible at the soil surface to protect against erosion and to use as a food source for certain soil organisms such as earthworms. Noninversion tillage is preferable. If possible, perform tillage only in the seed zone. There are two different schools of thought regarding the usefulness of shattering below the soil surface. One school of thought is that maximum shattering is desirable to provide maximum channels for water infiltration, aeration, and root penetration. The disadvantage of this approach is that the soil is more susceptible to compaction after tillage, hence the need to limit traffic after the tillage operation. The second school of thought promotes creation of widely spaced slots for root penetration, water infiltration, and air exchange in an otherwise firm soil matrix. The firm soil between the slots will provide support for field traffic, and the slots will stay intact. However, a smaller soil volume will be available for root exploration in this approach as opposed to that of the former. The depth of a compact layer should dictate the depth of tillage. Tillage depth should be set an inch or two below a compacted pan, if this is present. If a compacted pan is not present, there is no reason to perform deep tillage.

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