



# SOIL COMPACTION

**Sustainable Practices for  
Protecting Farmland From  
Long-Term Soil Damage**

By Steve Vandegrift  
Product Manager  
Alliance Tire Americas, Inc.

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# Year after year, soil compaction squeezes yields and profits from millions of acres of American cropland

It's an invisible epidemic, often mistaken for nutrient deficiency, drought stress, herbicide damage or "wet feet," and its consequences can last for years.

The effects of soil compaction can take many forms:

- Roots can't penetrate compacted soil to reach nutrients and water.
- Shallow root systems inhibited by compaction zones make crops more susceptible to drought stress.
- Unused nutrients, out of reach of stunted roots, may leach, run off or volatilize into the atmosphere, leading to significant waste of fertilizer dollars.<sup>1</sup>
- Compacted soil lacks the tiny spaces needed to diffuse and store oxygen and water, which are vital to crops as well as to the microbial community that cycles nutrients in the soil.
- Water infiltration can be severely limited in compacted soil. The result is runoff after rainfall—which can create destructive erosion—and poor replenishment of soil moisture. In fact, compacted soils in variable weather conditions can create the worst of both worlds: waterlogged soils that eventually dry out and can't be replenished due to poor infiltration.
- Compacted soils are much more prone to denitrification, especially in wet years, speeding the loss of valuable nitrogen fertilizer.<sup>2</sup>
- Tight soils require significantly more energy to till or cultivate than healthy, well-structured soils do, which can cause fuel bills to skyrocket.

## Devastating Yield Impacts

A wide range of variables influence soil compaction, from the ground pressure applied by equipment and the moisture content of the ground during fieldwork to the structure of the soil itself. Despite the range of impacts—with yield losses ranging from 14% to 70%—it's clear that compacted soils can severely limit productivity.

Yield impacts can vary according to weather. Prime growing conditions can minimize the impact of soil compactions on crop health. But in dry years, stunted roots may fail to reach vital water reserves. In wet years, the lack of oxygen in compacted soils can drown tender roots.<sup>3</sup>

Meanwhile, runoff from compacted fields can contribute to water pollution in the form of excess nutrients, sediment and chemicals. In short, soil compaction is a recipe for economic and environmental problems.

**Soil compaction is so devastating and widespread it's been called "a global threat to sustainable land use" by soil scientists<sup>4</sup>**

## Wasted Time, Wasted Fuel

The added difficulty of pulling equipment through compacted soils can quickly drag the profit out of fieldwork. One study logged 35% higher fuel consumption in tilling compacted soil.<sup>5</sup> Another experiment, in Illinois, charted a 10-to-16-fold increase in energy use for tillage at low speed in compacted soil and 4-to-8-fold increases in energy required for high-speed tillage.<sup>6</sup>

It's not just harder to work compacted soils. Poor drainage can delay the start of fieldwork by days. Not only is sitting on the edge of a field waiting for it to dry frustrating, but delayed planting of many crops after optimum planting dates is widely known to reduce yields.

3 - Soane and Van Ouwerkerk (1998)

4 - DeJong Hughes (2009)

5 - Raghavan et. al. (1990)

6 - Duiker



Ironically, the race to complete fieldwork, planting or harvest in slow-draining soil can create a cycle of destruction, luring farmers to work wet soils that are even more susceptible to compaction than when they're adequately dry.

## If the soil structure is “broken” by vehicle traffic, it can take years to rebuild

### Secrets of the Soil

Soil compaction is largely a matter of physics. The soil in your field isn't a solid mass — on a microscopic level, it's a massive pile of sand, silt and clay, bits of organic matter, billions of microbes, and glue-like substances that hold pieces together like mortar in a brick wall. Between particles, micropores capture air and water in tiny, empty spaces that can be pumped out by roots. Larger macropores also harbor water in spaces big enough to allow gravity to drain water deeper into the soil profile. Cracks from freeze/thaw cycles and burrows created by earthworms, insects and old roots create a vast network of channels that allow the soil to breathe and roots to grow.

Think of the soil as a stone bridge. Some bridges are stronger than others due to their design, structure and materials. Soils are similar—there's a breaking point, and some soils are particularly prone to collapse under heavy loads.



This soil pit experiment illustrates that a bias-ply tire under higher inflation pressure (right) exerts more compaction force on the soil than a radial flotation tire with lower inflation pressure (left).

## Healing Compacted Soils

Increased tillage or deep ripping can break up compacted soil layers, but can also result in the loss of organic matter and the destruction of soil microbial communities. Tilling can actually make many soils more prone to further compaction by breaking up their natural structure.

Nature's solution to soil compaction is the swelling and shrinking of soils as they undergo cycles of wet/dry and frost/thaw, but that process is slow and it can take many years to rebuild native structures. One compaction study on a logging site found that impacts lasted for 23 years, and anyone who has seen the ruts of pioneer wagons along the old Santa Fe Trail or Oregon Trail knows that the impact of severe compaction can last for generations.

The extremely deep compaction—several feet below the soil surface—that can occur with today's very heavy machinery is hard to break up even with deep-freezing soils. A pair of researchers from the U.S. and Sweden wrote of compaction from high axle loads, "at depths of more than 40 cm (16 in.) it is virtually permanent, even in clay soils in regions with annual freezing."<sup>7</sup>

Planting deep-rooted cover crops, including tillage radish, clovers, cereal rye, oats and others can break up compaction and—especially in the case of fibrous-rooted cover crops—protect soils from further compaction by diffusing the weight of machinery that drives over them. There are also a number of other soil-building benefits to planting cover crops which are outside the scope of this paper.

## Preventing Compaction

The good news is this: Unlike with droughts or flooding there are things you can do to reduce the damaging long-term effects of soil compaction. The keys to prevention are how you operate your equipment and how you select and manage your tires.

The most fundamental approach to reducing soil compaction is minimizing the amount of load your soils are subjected to, and the number of times you drive across them.



## Compaction Cuts Yields

The yield impact of soil compaction can vary widely by soil type, crop and weather conditions, but one trend is clear—compacted soils can have a devastating impact on production. Consider these results from university studies around the world:

- Corn lost 24% of its yield and sorghum yields fell by 39% in an American study of compaction in heavy soil<sup>1, 8</sup>
- Wheat yields fell by 50% in a British compaction experiment.<sup>9</sup>
- Corn yields suffered by as much as 70% in severely compacted soils in a Quebec study.<sup>10</sup>
- Cotton yields dropped by 28% in a compaction study in Spain.<sup>11</sup>
- Silage corn output fell by 38% in a Dutch study of soil compaction caused by heavy axle loads.<sup>12</sup>
- Alfalfa yields dropped by 36% after six passes across the field in a Penn State Study.<sup>13</sup>
- A compaction study covering seven countries in North America and Europe found a 14% average yield decrease due to repeated wheel traffic, as well as decreases and delays in emergence.<sup>14</sup>

7 - Håkansson and Reeder (1994)  
8,9,10,11,12 - Ishaq et. al. (2006)  
13 - Duiker  
14 - Taser and Kara (2005)

Before driving out onto the field for any reason, ask yourself these questions:

- Do you really need to be out there?
- Are conditions appropriate for traffic, or would it be better to wait until the soil is a little drier?
- Is a fully loaded rig—for instance, a manure tank or a feed wagon—too heavy for the situation? Would your soils be better off if you worked with half or three-quarters of a load?
- Have you removed excess weights from your tractor when they're not needed?



Layers of wood chips and soil reveal the compaction force of a full manure tanker on the soil. Radial flotation tires and lower inflation pressure reduce that force dramatically, minimizing compaction and keeping it in the upper few inches of the soil.

Next, consider where you should drive. Avoid wet spots and low areas if you can, and consider establishing and following controlled traffic lanes. Controlled traffic, or tramlines, is a widely used tactic—particularly in Australia and Europe—to confine soil compaction to clearly defined tracks. All machinery, from tractors performing fieldwork to planters and sprayers, will follow the same set of wheel tracks. Tramlines work not just because of soil physics, but also because of plant biology. Research indicates that plants encountering compaction on one side can compensate by bulking up their root systems on the uncompacted side.

## With GPS guidance systems and automatic steering technology, tramlines are easier than ever to maintain



Tire design and inflation pressure have huge impacts on the footprint of a farm tire. A larger footprint distributes weight over more surface area, helping reduce soil compaction.

### Choose the Right Tires

Tires are the key piece of equipment in managing soil compaction from machinery because they translate the weight of the machine into downward force on the soil. The larger the footprint of the tire, the more surface area can absorb the weight of the equipment; looking at it the other way, a small footprint concentrates the force onto a smaller area, resulting in more compaction.

That's why flotation tires, duals or even triple-tire fitments are used on extremely heavy machinery—they spread the load across a greater surface area. Radial tires, whose flexible sidewalls bulge near the soil surface to maximize footprint, also aid in reducing compaction.

Where narrow tires are needed—for instance, on sprayers or in fields with tramlines—tall tires help create a larger footprint.

Consider your needs and work with your tire dealer to find the tire with the size, shape and load rating you need.

## Minimize Inflation Pressure

The ground pressure exerted by equipment will be 1 to 2 pounds per square inch (psi) greater than the tire's inflation pressure. That means a tire inflated to 18 psi will exert about 20 psi of ground pressure on the soil. The same machine riding on tires inflated to 30 psi will exert a force of approximately 32 psi on the soil. As a result, minimizing inflation pressure is the most fundamental step in minimizing soil compaction.

There's no single "right" inflation pressure, and it is critically important to consult manufacturers' charts to determine the optimum inflation pressure for a specific machine in a particular situation—it will vary by load, the speed of travel and the construction of the tire.

As inflation pressure increases, the tire's footprint becomes shorter and narrower, and downward force is concentrated increasingly toward the center of the contact patch. That can increase soil compaction and cause greater wear on the center of the tread.

Conversely, under-inflating your tires can cause them to become unstable, resulting in poor handling and damage to the tires through overheating, uneven tread wear and bead stress. Avoid those problems by always referring to your tire manufacturer's recommendations.



## Quick Tips: Determining Optimum Inflation Pressure

To determine the proper inflation pressure for a tire, consult the manufacturer's chart for that model and size of tire and follow these steps:

- Find the maximum speed.
- Scan down the column to find the axle weight based on the weight of the fully loaded machine.
- Use the chart to locate the proper inflation pressure, which is typically expressed in both psi and bar.

Be sure to include the weight of fuel, spray, fertilizer, grain, manure or water when calculating load; also remember to account for the weight of implements on your drawbar. If you're going to be operating on sidehills, consult your tire dealer for advice on how to account for extra load on the downhill tires.

Don't forget to recalculate optimum inflation pressure when situations change—for instance, when a tractor is hitched to a lighter implement, or when you're going to be running at slower speeds—and adjust your inflation pressure accordingly. It just takes a few moments, and could make a huge difference in soil compaction and safety.



Tires inflated to their optimum pressure will transmit the minimal amount of ground pressure while safely carrying the desired load at an appropriate speed. Properly inflated tires also have the benefit of transferring more torque from the equipment to the ground reducing slippage by as much as 26%.<sup>16</sup>

Maximum tire flotation on the soil surface also reduces the “bulldozing” effect, in which overinflated tires push soil in front of themselves, burning energy with every revolution as they try to climb over the pile of soil they’ve created. This “bulldozing” can add 14% to 20% to your fuel bill, according to a study at South Westphalia University of Applied Sciences in Germany.<sup>15</sup>

## **A properly inflated tire expends more energy on providing forward motion and less on compacting precious soils**

Using the largest possible radial tires on your equipment and having them at the proper inflation pressure can help reduce soil compaction and improve equipment performance. In the short term, those benefits appear immediately at the diesel pump and in a healthy crop. By the end of the season, you’ll see the boost in the bin and at the bank—and you’ll enjoy the returns of reduced soil compaction for years to come, in the depths of your soil.

Visit [www.atgtire.com](http://www.atgtire.com) for load/inflation charts for Alliance, Galaxy and Primex tires.



## References

- Batey, T. 2009. Soil compaction and soil management: A Review. *Soil Use and Management*. 25: 335-345.
- Duiker, S.W. Effects of soil compaction. Pennsylvania State University Bulletin UC188. Accessed 17 July 20014 at <http://extension.psu.edu/plants/crops/soil-management/soil-compaction/effects-of-soil-compaction>.
- Gelder, B.K., R.M Cruse and X.Y. Zhang. 2007. Comparison of track and tire effects of planter tractors on corn yield and soil properties. *Transactions of the ASABE* 50(2): 365-370.
- Håkansson, I. and Reeder, R.C. 1994. Soil compaction by vehicles with high axle load—extent, persistence and crop response. *Soil and Tillage Research*. 29:2-3; pp. 277-304.
- Hoorman, J. J., Sá, J. C. M. and Reeder, R. 2011. The biology of soil compaction. *Crops and Soils*. July-August 2011, 4-10.
- De Jong Hughes, J. 2009. Tires, traction and compaction. University of Minnesota Extension. Accessed 17 July 2014 at <http://www.extension.umn.edu/agriculture/tillage/tires-traction-and-compaction/>.
- Ishaq, M., M. Ibrahim and R. Lal. 2006. Compaction and crop yield. *Encyclopedia of Soil Science* Vol. 2. CRC Press, Boca Raton, Fla.
- Raghavan, G.S.V., P. Alvo and E. McKeyes. 1990. Soil compaction in agriculture: A view toward managing the problem. In *Advances in Soil Science*. Vol. 11: 1-36.
- Raine, M. 2013. Fuel savings rationale for flatter tires. *The Western Producer*. 21 November 2013. Accessed 17 July 2014 at <http://www.producer.com/2013/11/fuel-savings-rationale-for-flatter-tires/>.
- Soane, B.D. and C. Van Ouwerkerk. 1998. Soil compaction: A global threat to sustainable land use. *Advances in GeoEcology* 31:517-525.
- Taser, O.F. and O. Kara. 2005. Silage maize (*Zea mays L.*) seedlings emergence as influenced by soil compaction treatments and contact pressures. *Plant, Soil and Environment* 51 (7): 289-295.
- Wood, R.K. and D.A. Mangione. 1994. Let the air out: Advantages of properly adjusted radial tire pressures. Ohio State University Extension. Fact Sheet AEX-530-94. Accessed 17 July 2014 at <http://ohioline.osu.edu/aex-fact/0530.html>.

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201 Edgewater Drive, Suite 285  
Wakefield, MA 01880  
800 343-3276  
[www.atgtire.com](http://www.atgtire.com)

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