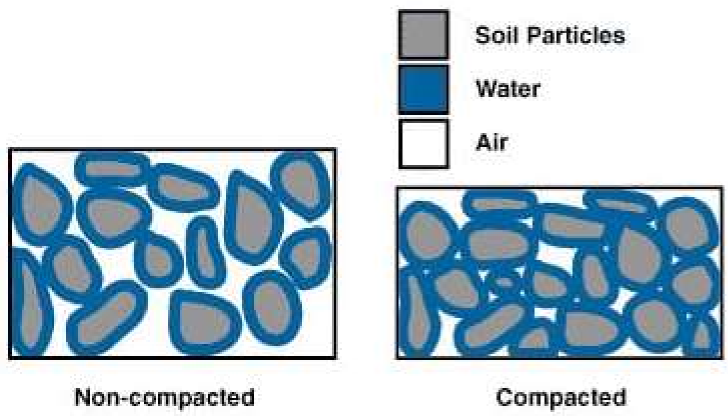
Compaction and Soil Health

June 2022

What is soil compaction?

Soil compaction is an important soil health constraint. Compaction occurs when soil particles are compressed closer together, reducing the size of pores between soil aggregates. Reduced pore size limits water and air infiltration through the soil profile, which are essential for proper root growth and nutrient movement.



[DeJong-Hughes, J., et al. 2004]

Effects of soil compaction

When compaction occurs, there are several constraints for plant growth, including:

- Poor drainage
- Reduced nutrient uptake and nutrient availability
- Increased risk of erosion
- Reduced aeration, resulting in less oxygen for plant roots in the root zone
- Impaired root growth
- Less space for water and air to enter and infiltrate through the soil
- Increased potential for loss of plant-available nitrogen through denitrification
- Impeded plant emergence (through crusting on soil surface)
- All leading to potential reduced yields

Causes of soil compaction

Soil compaction largely occurs as a result of human activities where physical stress causes soil particles to compress. The main causes of soil compaction in agriculture are heavy equipment traffic and tillage implements. Contributing factors such as high soil moisture, low organic matter content in the soil, and/or higher clay content in soils, can all contribute to the amount of compaction that occurs. Additionally, some surface compaction can occur naturally from substantially heavy rainfall when soil is bare.

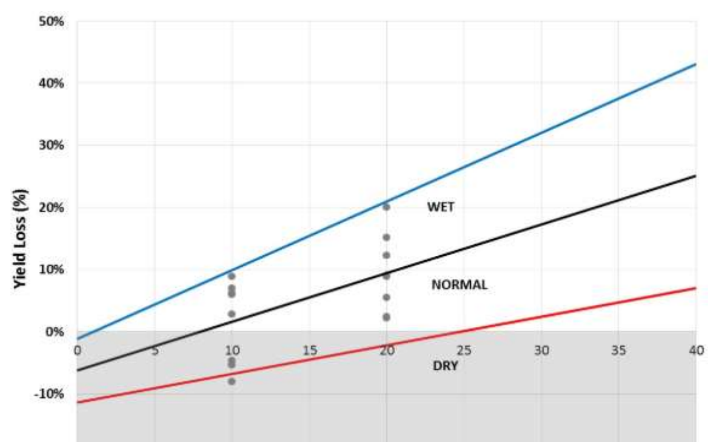


Figure 1. An example of yield loss due to compaction at various axel loads under wet, normal, and dry field conditions. [Shearer and Fulton, 2017]

Measuring Soil Compaction

A suggested approach for assessing soil compaction is the use of **penetrometers**. Penetrometers are tools that can be used to measure compaction in the soil surface and sub-surface layers when inserted into the ground. Penetrometers measure resistance to penetration through various physical means and can be expressed in different metrics, including pounds per square inch (PSI) of force. Resistance to penetration has a direct relationship with root penetration, so, penetrometers can be a useful tool to gauge the presence and severity of compaction in agricultural systems.

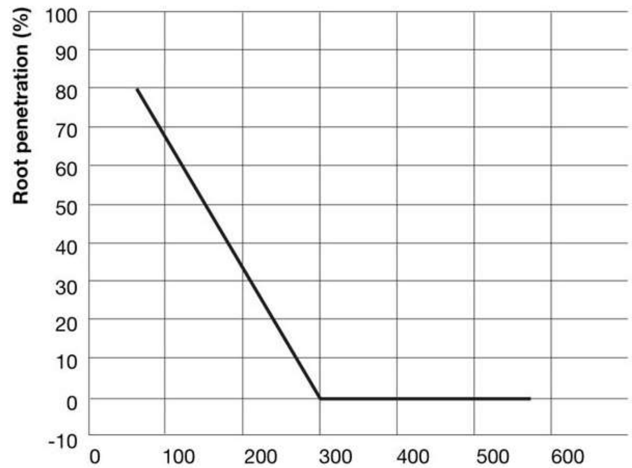


Figure 2. Linear relationship between penetration resistance and root penetration. [Duiker, S.W, 2002]

Taking compaction readings using penetrometers **<u>must be done</u>** when the soil moisture is at **field capacity** (24-48 hours after a soaking rain so that free drainage has occurred). In order to get reliable data, penetrometer testing should be avoided in early spring due to the potential for frost, as well as the dry months of summer.

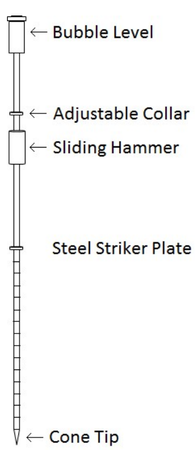
Collecting and Interpreting Compaction Data Using Penetrometers

The PEI Department of Agriculture and Land has developed an operating procedure for measuring compaction using static penetrometers. Instructions for collecting compaction readings and self-reporting results using a calculator developed by the PEIDAL, are available in the *Using Penetrometers to Measure Soil Compaction* factsheet.

<u>Types of Penetrometers</u>

There are two main types of penetrometers that can be used for assessing soil compaction:

- <u>Static Penetrometers.</u> Static penetrometers have a T-handle for applying force, a steel shaft with graduated markings for depth measurements, a cone tip for soil penetrations, and a pressure gauge that indicates PSI. Basic static penetrometers are analog and must be read manually at the chosen depths. Electronic or digital static penetrometers will provide a digital readout of penetrometer results and depth, and may log data and GPS location, depending on the model. The PEIDAL self-reporting tool uses this type of penetrometer.



- <u>Drop Hammer (Dynamic) Penetrometer</u>. Drop hammer penetrometers (also known as dynamic penetrometers) use a sliding weighted hammer mounted on the shaft to drive the cone tip into the ground without the need of an operator manually exerting force. This has the advantage of removing operator strength as a variable for getting compaction readings. The Kensington North Watershed Association, in conjunction with Agriculture and Agri-Food Canada, has done significant research on developing a relationship to relate drop hammer "drops" with root penetration resistance.

Mitigating Soil Compaction

Equipment Weight

Farming equipment plays a substantial role in causing soil compaction, and with farm equipment increasing in weight and size, it is becoming more difficult to mitigate compaction in fields. There are two main equipment factors when considering the risks of compaction: axel load and tire pressure.

Axel load largely affects subsurface compaction (deep compaction), where tire pressure largely affects surface compaction. To mitigate deep compaction, axel loads are generally recommended to be below 10 ton per axel. Axel load can be reduced by adding more axles or reducing load weight. Tire pressure should be kept to 15 psi or lower to reduce surface compaction (Table 1).

Table 1. Axel load and tire pressure affect different depths of compaction and require different mitigation actions.

Compaction Source	Compaction Zone	Recommended Thresholds	Recommended Action
Axel Load	Subsurface (deep)	Less than 10 tons per axel	Smaller loads; Increased no. of axels
Tire Pressure	Surface	Less than 15 PSI	IF/VF radial tire technology; Central inflation systems

Traffic

Timing and frequency of equipment traffic can play a significant role in overall compaction in the field.

Timing: Compaction effects are compounded by soil moisture. **Delaying operations when conditions are wet** will aid in mitigating compaction.

Frequency: **Using controlled traffic** leads to a smaller percentage of compaction on the overall area of the field. The first pass with compaction equipment causes the greatest compaction and without controlled traffic, often up to 70-80% of the field becomes tracked by equipment for certain cropping systems. Keeping multiple passes to specific traffic areas (i.e. tramlines) with have a net reduction in compaction on the total area of the field.

Signs of soil compaction

Symptoms of soil compaction can be observed visually in several ways. Here's what to look for:

- Areas within a field that consistently produce poor crop growth year-after-year across different crop types
- Patterns in growth issues that follow wheel tracks, hauling trails, windrows, etc.
- Crusted soil surface. This can be easily observed if a hard soil crust has formed that is plate-like and horizontally layered.
- When using a shovel to reveal the subsurface, the presence of horizontal root growth, and hardpan.

Figure 3. An example of stunted crops due to soil compaction.

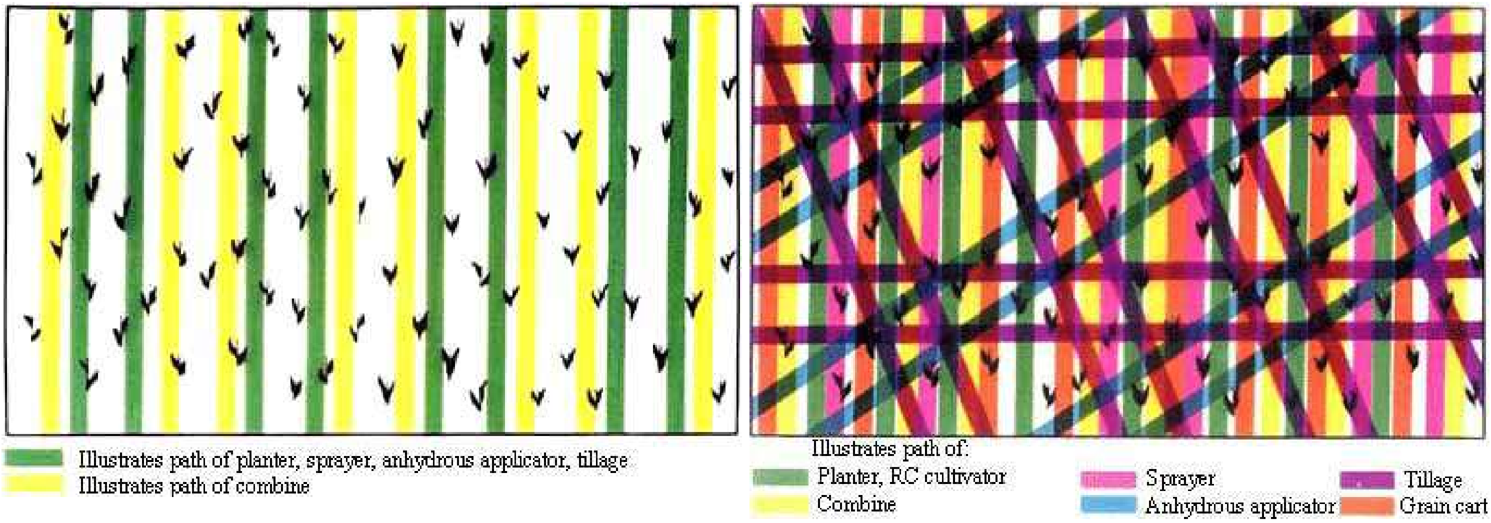


Figure 4. Controlled traffic (left) versus uncontrolled traffic (right) in a corn rotation. *[Jones et al. 1989]*

Tillage

Tillage, while necessary in many cropping systems, has been shown to negatively impact soil aggregate stability and organic matter, both of which act as natural resistance to soil compaction. Reducing the frequency of tillage events over a rotation can be beneficial for reducing the severity of compaction events through maintaining a more resilient soil structure. Furthermore, when soils are too moist, tillage will cause smearing of the soil and will contribute to the development of a compaction layer directly below the depth of tillage, known as hardpan.

Organic Matter and Aggregate Stability

Healthy soils that are high in organic matter and aggregate stability will have a better ability to naturally resist compaction. Organic matter near the surface acts as a cushion for compaction, as it can compress and maintain its structure, much like a sponge. Organic matter plays a large role in the formation of micro- and macro- soil aggregates and the diversity and stability of these aggregates help to resist compaction. Applying organic amendments (such as manure), growing diverse rooted cover crops, and reducing tillage are among some of the soil health principles that drive organic matter and aggregate stability. For more information, see Section 2 of *PEI Soil Health Test – How To Interpret Your Results* factsheet.

Correcting Soil Compaction

There are some actions that can be taken for correcting soil compaction however, these strategies are short term corrections that often will not remedy the entirety of effects from previous compaction events. Furthermore, correcting soil compaction events is not sustainable if the compaction factors are not mitigated for future field management. Mitigating the risks of compaction is thought of as the most valuable strategy for combating compaction in agricultural systems.

Freeze-thaw cycles

In Prince Edward Island's climate, some natural compaction alleviation occurs through frost cycles. This alleviation is restricted to the depth of frost, which varies from winter to winter and does not reach deep compaction zones. Frost shattering of soil compaction provides only a small amount of correction and alone will not offset the amount of compaction typically occurring on farms.

Subsoiling / Deep Ripping

Subsoiling is commonly used to correct deep (subsurface) compaction. During subsoiling, shanks are used to reach depths greater than typical tillage implements to break up, or shatter, compaction zones. Subsoiling must be done when the soil is dry to avoid causing smearing in the subsoil, which can worsen compaction. Subsoiling should be timed correctly in the season so a crop can be established before the next heavy equipment traffic occurs. Crop establishment is important so that the newly shattered soil can be held in place by roots. Subsoiling can be costly and the effects of subsoiling on improving yields can be inconsistent in compacted systems.

Cover Crops

Generally, having cover crops with diverse living fibrous roots helps to build soil, which in turn can help mitigate compaction. A good mix of fibrous root and taproot cover crops across rotations will create an ideal scenario for building organic matter and promoting a biodiverse soil food web. Deep rooted systems will help create channels downward through the soil profile which can reduce compaction, however, there is limited evidence that growing a taproot cover crop will improve compaction in a single season. Note that crops advertised to help with deep compaction issues, such as tillage radish, may not be able to penetrate a hardpan. Digging with a shovel can provide a great assessment of how well taproots are penetrating plow pans (look for sideways root growth or the crops growing upward out of the soil surface rather than through the hardpan).

For more information, please contact the PEI Department of Agriculture and Land at: (902) 368-4880.

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