Using Penetrometers to Measure Soil Compaction

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Why Measure Soil Compaction?

Soil compaction is a common soil health issue that affects the soil's ability to support plant growth and can limit the soil's ability to function in reducing water, air and nutrient movement. The PEI Soil Health Testing suite uses a variety of biological, physical, and chemical indicator tests to assess soil quality in a laboratory setting, however, to accurately detect the presence and severity of soil compaction, it must be assessed in field. This factsheet will provide a self-reporting method for collecting compaction data and a Microsoft Excel template to record and visualize results related to the depth and severity of compaction in a field. For background information on the causes, effects and control of soil compaction, please see **"Compaction & Soil Health"** factsheet.

Measuring Soil Compaction

Quick Assessment – The Shovel Method

For a quick assessment to find compaction layers and determine their depth, digging a small test pit can provide useful information. Compaction can be felt while digging with a shovel, and compacted layers should be visible on the sidewall once the pit is dug. This will not provide a degree of compaction for the entire field, but it can provide a quick answer to the relative depth of a compaction zone in the field.

Detailed Assessment - Penetrometers

Penetrometers measure resistance to penetration through various physical means and can be expressed in different metrics, including pounds per square inch (PSI) of force. Penetrometers provide a standardized approach for assessing soil compaction in the soil surface and sub-surface layers, as resistance to penetration is directly related to root penetration in the soil (Figure 1). If used properly, penetrometers can be a useful tool to gauge the presence and severity of compaction in agricultural systems.

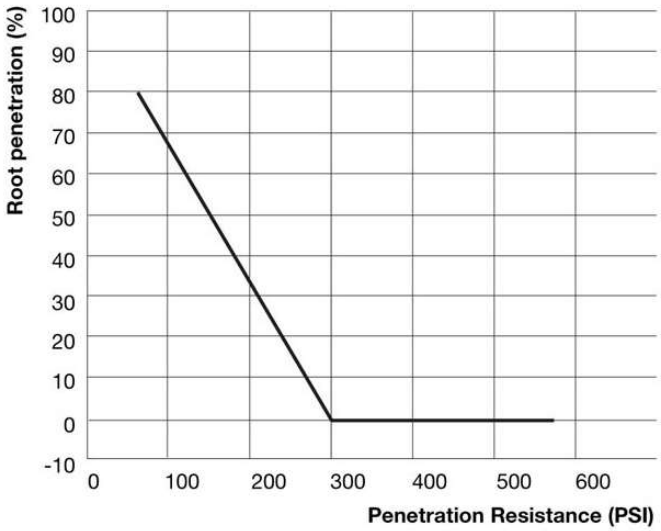

Figure 1. Visualization the relationship between penetration resistance and root penetration. [Duiker, S.W, 2002]

Conditions for using Penetrometers

In order to get **useful and accurate** soil compaction measurements using a penetrometer, several important conditions should be followed:

- Field conditions: Compaction readings should be taken in unfrozen soil during moist-to-slightly dry field conditions. Dry or frozen soils can be hard to penetrate and can result in misinterpreted compaction readings. Compaction readings are best taken **24-48 hours after a soaking rain**, where time has allowed for free drainage. Fall is an ideal time to take compaction readings, as the dry summer season should be avoided. Frost pockets can occur in early spring, which could be mistaken for compaction layers. Late spring may provide good conditions for testing.

- Equipment conditions: Penetrometers should be calibrated and in good working order. Penetrometers often come with two interchangeable cone tips (½ inch and ¾ inch). For PEI soils, the ¾" inch cone tip is usually appropriate. If significant wear in the cone tip is visible, consider replacing it.

Suggested Method for Sampling with a Penetrometer

When taking penetrometer readings, taking several measurements in different areas of the field will provide a better representation of compaction for that field. The greater the number of areas sampled, and the more depths readings that are taken, the more representative the results. The compaction tool allows for up to 40 points at 3-inch intervals for a single field, however the user may select a smaller number of points that is suitable for feasibility and field size. At least six points should be sampled to at least a 12-inch depth to ensure accuracy. Areas of the field that are not representative (steep slopes, rocky areas, low areas, etc.) should be avoided. If you have an existing grid or management zone division in your fields, this can provide some guidance for sampling.

Static Penetrometer. Duiker, S.W, 2002

There are two types of penetrometers: static and dynamic. **Static** penetrometers, the most common type, have a T-bar handle and require the user to push down on the penetrometer, which is spring-loaded and connected to a pressure gauge or electronic sensor. These types of penetrometers give a PSI reading, which can be interpreted through the PEIDAL Excel compaction interpretation tool. **Dynamic** penetrometers, also known as **drop-hammer** penetrometers, use a sliding hammer weight to force the cone-tip into the ground. The number of "drops" needed to push the cone through each depth can be used to assess soil compaction. For more information on types of penetrometers, see "**Compaction & Soil Health**" factsheet.

*Directions for using a **static** penetrometer:*

1) Ensure that you are using the ¾" tip and that you have chosen to collect measurements during appropriate field conditions (described above). It can often be easier to measure compaction with two people- one to record data, and one to operate penetrometer and read off measurements.
2) Print off a blank static penetrometer data sheet (final page of this document) and record the date, field ID, and any relevant notes.
3) Familiarize yourself with the instrument, and clear off any debris from soil surface before beginning the measurement.
4) At each collection point, insert the tip of the penetrometer barely into the soil then apply enough force so that you are penetrating at a slow and consistent speed. Ensure that the penetrometer is level. Monitor the gauge and record the highest number for the current depth range (1-3, 4-6, etc.).
5) Continue to take gauge readings at each interval to the depth you are interested in (up to 18 inches, minimum of 12 inches). If you cannot or decide not to measure to the 18-inch depth, leave the columns blank after the last reading. If you strike a rock or hit a sudden air pocket that causes you to miss several readings, simply move to an adjacent location and start over at the surface with a new reading.

Using the Excel Compaction Interpretation Tool

1) Download the Excel .xls file
2) Open the file and immediately choose File > Save As and give it a meaningful name that includes the field ID. Each field will have its own Excel file, so repeat these steps for each new field.
3) Enter the field information and the penetrometer data you collected in the field into the appropriate cells under the 'Compaction Data' tab. For any measurement points or depths that weren't measured, **leave those cells blank**.
4) Once the data for that field is entered in the 'Compaction Data' tab, select the 'Results' tab to view your results. Save the completed file again.

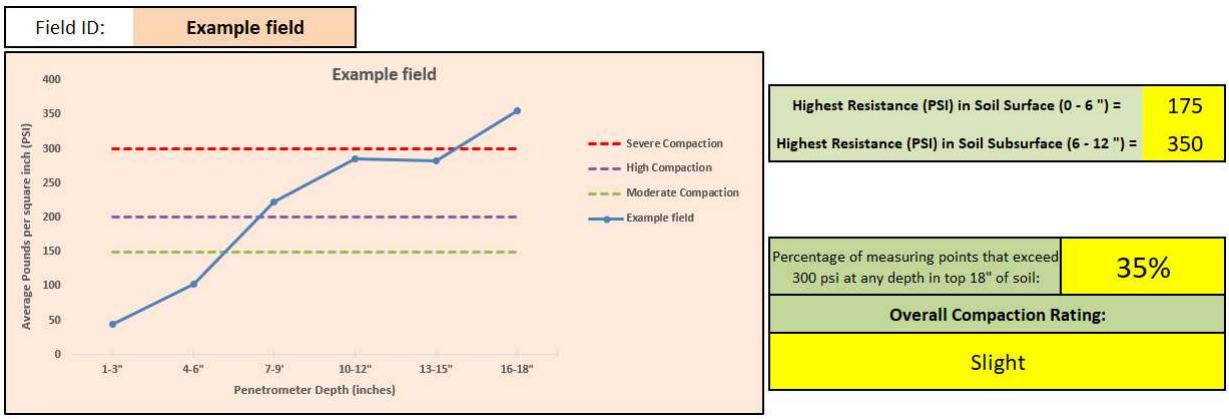

Figure 2. Example of a completed interpretation tool, with a compaction chart showing average resistance to penetrometer at each depth for a field.

Interpreting the Compaction Results and Ratings

Under the "Results" tab, you will find a compaction chart and ratings. The chart represents the average compaction **across the field** at each depth (Figure 2). This will help you understand the depths at which you may have compaction issues (indicated by crossing the medium, high, and severe dotted lines). Spikes in the graph will indicate compaction layers that may need to be addressed.

The text box to the top right of the graph shows the maximum penetrometer resistance in the surface (0-6" depth) and the subsurface (6-18" depth). This helps to understand if compaction issues are occurring in one or both depths of the soil profile. See **"Compaction & Soil Health"** factsheet for information on the causes of surface and subsurface compaction.

The box to the bottom right of the graph shows the percentage of sampling locations that you tested in your field that have a reading of greater than 300 PSI in the top 18 inches. This is used to calculate the overall compaction rating for your soil based on a scale developed by the University of Kentucky for compaction in agriculture. These ratings are listed in Table 1 below.

It is important to note that one individual compaction reading is not likely representative of the whole field. When looking at your compaction data, try to determine if there are trends in your data, or general depths that may show increased compacted results, and try to address the compaction issue at that depth or 1 to 2" deeper.

Table 1. Overall field compaction ratings. Duiker 2002; adapted from Murdock et al. 1995.

Percentage of measuring points having a cone index reading of > 300 psi	**Compaction Rating**
< 30 %	Little-None
30 – 50 %	Slight
50 – 75 %	Moderate
> 75 %	Severe