Cornell University
School of Integrative Plant Sciences

Soil Health Manual Series Fact Sheet Number 16-06

Surface and Subsurface Hardness

Surface and subsurface hardness are indicators of the soil compaction status, measured as field penetration resistance in pounds per square inch (psi). It is measured in the field using a penetrometer or soil compaction test pushed through the soil profile at two depth increments (surface: 0 – 6", and subsurface: 6 – 18"). Measurements should be taken when the soil is friable, since moisture content influences the measurement. For a detailed guide on how to take penetrometer measurements please visit bit.ly/SHPenetrometer.

How soil hardness relates to soil function

Field penetration resistance measures whether the soil is compacted. Compaction occurs when large pores are packed closer together through tillage or traffic with heavy equipment, particularly on wet soils. Large pores are necessary for water and air movement and to allow roots and organisms to explore the soil (Fig. 1). When surface soils are compacted, runoff, erosion, slow infiltration, and poor water storage result.

Subsurface hardness prevents deep rooting and causes poor drainage and poor deep water storage (Fig 2). After heavy rain events, water can build up over a hard pan, causing poor aeration both at depth and at the surface, as well as ponding, poor infiltration, runoff and erosion. Impaired water movement and storage create greater risk during heavy rainfall events, as well as greater risk of drought stress between rainfall events.

Most crop roots cannot easily penetrate soil with penetrometer readings above about 300 psi. Similarly, growth of mycorrhizal fungal hyphae and mobility of other beneficial soil organisms may be severely restricted by excessively hard soil. Since plant roots must be actively growing and exploring the root zone to access water and nutrients, crop quality and yield decline with compaction. Low growth increases weed pressure, and stressful conditions make crops more susceptible to pathogen pressure.

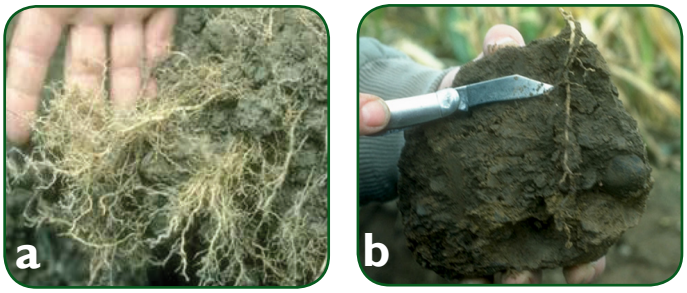

FIGURE 1 a and b. (a) Dense rooting allows for full soil exploration. (b) Surface compaction prevents root from accessing water and nutrients.

Managing and preventing constraints

Compaction in surface and subsurface soil occurs when the soil is worked or trafficked while it is too wet, and it can be transferred deep into the soil even from surface pressure. Thus, compaction can be prevented:

- avoid soil disturbance, especially when the soil is wet
- maintain aggregation
- target mechanical surface loosening of the soil, followed by adding fresh organic matter and rooting cover/rotation crops to build aggregates
- use deep tillage or deep rooting crops
- reduce tillage, have soil cover with active rooting, use rotations and controlled traffic with minimized loads to maintain non-compacted soils in the long term.

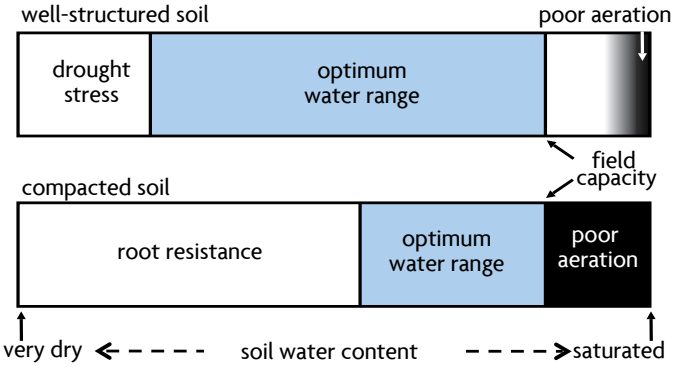

FIGURE 2. Compacted soils have greater root resistance, poorer water storage capacity and decreased infiltration compared to well-structured soils. *Source: Building Soils for Better Crops, 3rd edition.*

Surface and Subsurface Hardness

Basic protocol

Surface and subsurface hardness are measured using a penetrometer, an instrument that measures the soil's resistance to penetration. It consists of a cone-tip, a metal shaft, and a pressure gauge that measures resistance in psi (Fig. 3a).

- Most penetrometers come with two different sized tips which correspond to two different gauge scales. The outer and inner scales correspond to the larger ¾ inch and the smaller ½ inch diameter tips, respectively (3b). The ½" tip should be used for our test. The ¾" tip is for very soft soil. Be sure to use the scale appropriate for the tip size.
- The level of soil moisture can greatly affect the ease with which the probe penetrates the soil, and therefore the measured values. It is recommended that penetration readings be taken when the soil is at field capacity (2-3 days after free drainage). See Fact Sheet #5 for more detail on field capacity. If the soil conditions are not ideal, it is important to note these conditions at the time so that proper interpretation of the reading can be made.
- Apply slow even pressure so penetrometer advances into the soil at a rate of 4 seconds per 6 inches or less. Record the highest pressure reading measured for each of the two depths in the sample intake form. If you detect a hard layer, make sure to note its depth for your own reference.
- Field profiles of penetration resistance can be created by recording the measured psi every inch through the soil profile and then plotting them on a chart. These charts can be used to identify various layers of compaction, if present. For the soil health test, however, we only target two depths.

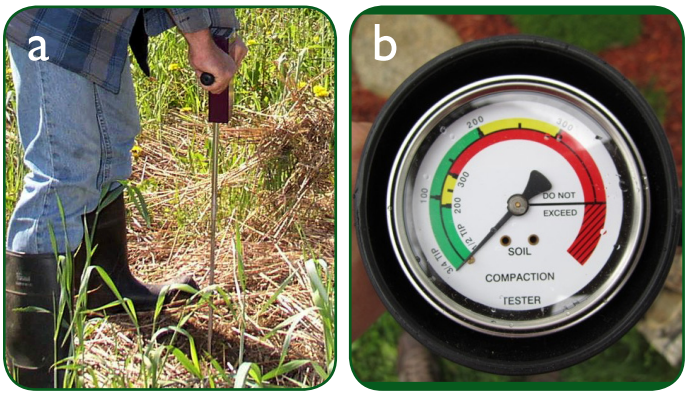

FIGURE 3 a and b. Measuring surface and subsurface hardness with a penetrometer. *Source (b): agriculturesolutions.com*

Scoring function

Figure 4 below depicts Surface (a) and Subsurface (b) Resistance scoring functions and upper value limits for coarse, medium, and fine textured soils.

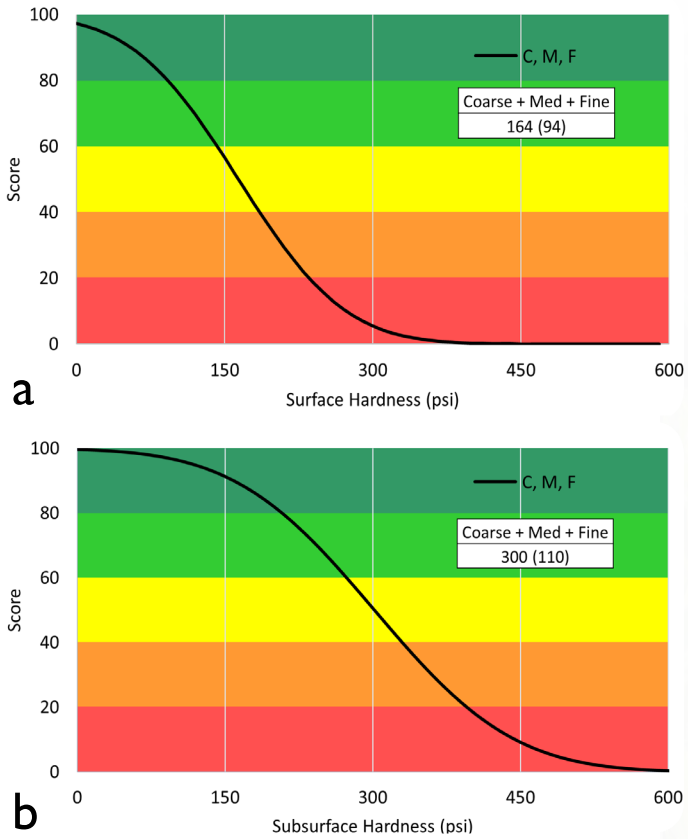

FIGURE 4 a and b. Surface (a) and subsurface (b) scoring functions and upper value limits for Coarse(C), Medium (M) and Fine (F) textural classes.

For a more comprehensive overview of soil health concepts including a guide on conducting in-field qualitative and quantitative soil health assessments, please download the Cornell Soil Health Manual at bit.ly/SoilHealthTrainingManual.

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For more information contact:

Cornell University

Soil Health Laboratory

bit.ly/SoilHealthContacts

Harold van Es

Robert Schindelbeck

Aaron Ristow, Kirsten Kurtz and Lindsay Fennell

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