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) using a field penetrometer pushed through the soil profile. It is measured in the field with a penetrometer or soil compaction tester for two depth increments (surface: 0 – 6", and subsurface: 6 – 18"). Measurements should be taken when the soil is near field capacity, since moisture content influences the measurement. The reading in psi can be converted to kilogram-force per square centimeter (kgf/cm^2).

Basic Protocol (guidelines for field user):

- 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 (Figure 2.18 A).
- 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 (B). For most instances, the ½" tip should be used. 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). If the soil conditions are not ideal, it is important to note conditions at the time so that proper interpretation of the reading can be made.

FIGURE 2.18 A and B. Measuring suface and subsurface hardness with a pentrometer.

- 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 – this is important information for management decisions.
- 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 (Figures 2.19 and 2.20). These charts can be used to identify various layers of compaction, if present. For the soil health test, however, we only target two depths.

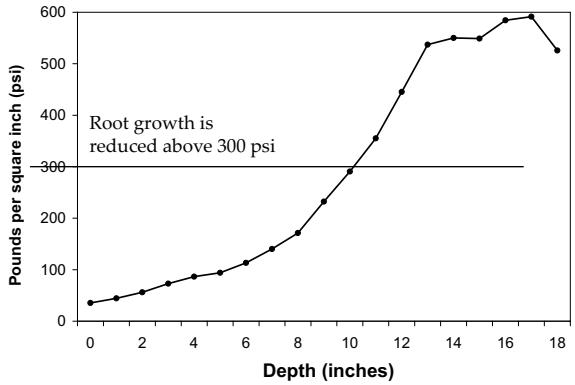

FIGURE 2.19. Soil compaction graph for a field in intensive vegetable production in 2005 (Courtesy of C.R. MacNeil).

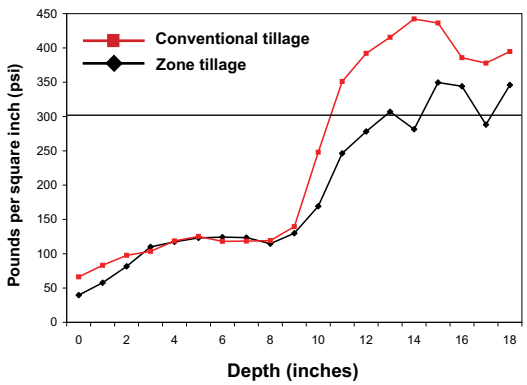

FIGURE 2.20. Soil compaction graph for a conventionally plow tilled field and zone-till field with deep ripping on the same farm in spring of 2005 (Courtesy of C.R. MacNeil).

How soil hardness relates to soil function:

Large pores are necessary for water and air movement and to allow roots and organisms to explore the soil. Field penetration resistance measures whether the soil is compacted. Compaction occurs when large pores are lost as solid soil materials are packed closer together through tillage or traffic with heavy equipment, particularly on wet soils. 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 (Figures 2.21 below and 2.22 on the following page). 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.

Managing and preventing surface and subsurface hardness constraints

Compaction in surface and subsurface soil occurs very rapidly when the soil is worked or trafficked while it is too wet, and compaction can be transferred deep into the soil even from surface pressure. Thus avoiding soil disturbance, especially when the soil is wet, can prevent compaction. Maintaining aggregation is particularly critical for preventing surface compaction (pages 15,44). Compaction can be alleviated by targeted management (Part III). Subsoil compaction can be addressed by deep tillage or by deep rooting crops. Surface compaction can be alleviated by targeted mechanical surface loosening of the soil, followed by fresh organic matter additions and vigorously rooting cover/rotation crops to strengthen and rebuild aggregates (pages 84-93). In the long term, reduced, well-timed tillage and controlled traffic with minimized loads, soil cover, rotations, and active rooting will maintain non-compacted soils.

Compaction from wet soil conditions: wheel traffic.

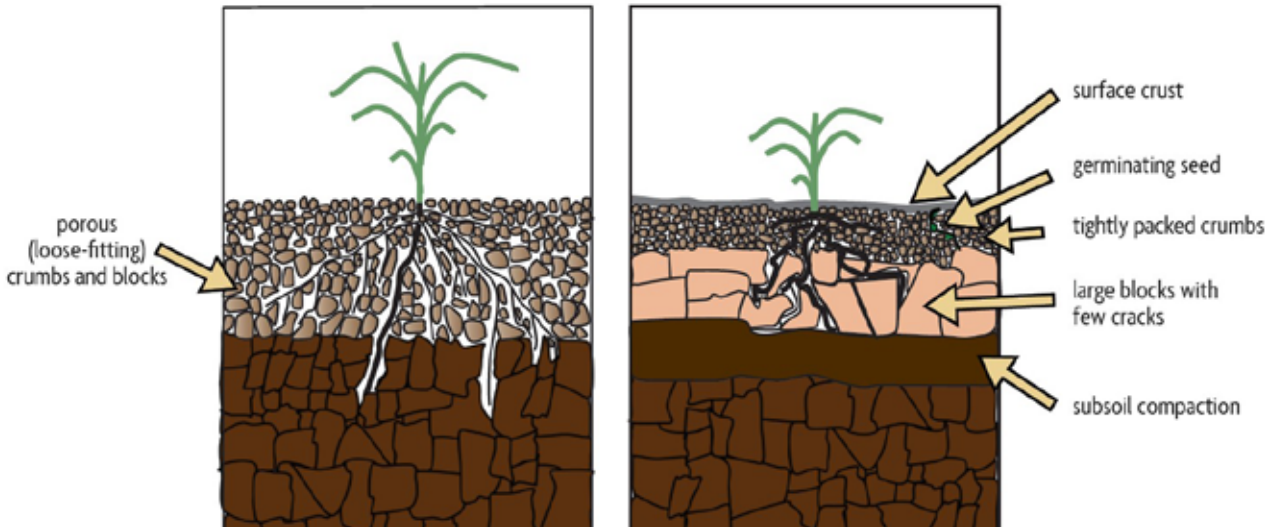

FIGURE 2.21. Plants growing is soil with good soil structure (left). Soil with three types of compaction: surface crusting, plow layer/surface compaction, and subsoil compaction (right). *Source: Building Soils for Better Crops, 3rd Edition*

Scoring function:

Below are the scoring function graphs for surface and subsurface resistance in coarse, medium, and fine textured soils (Figure 2.23). The red, yellow and green shading reflects the color coding used for the ratings on the soil health report (see page 71).

FIGURE 2.22. Dense rooting allows for full soil exploration (left). Surface compaction prevents root from acessing water and nutrients (right). *Source: Building Soils For Better Crops, 3rd Edition*

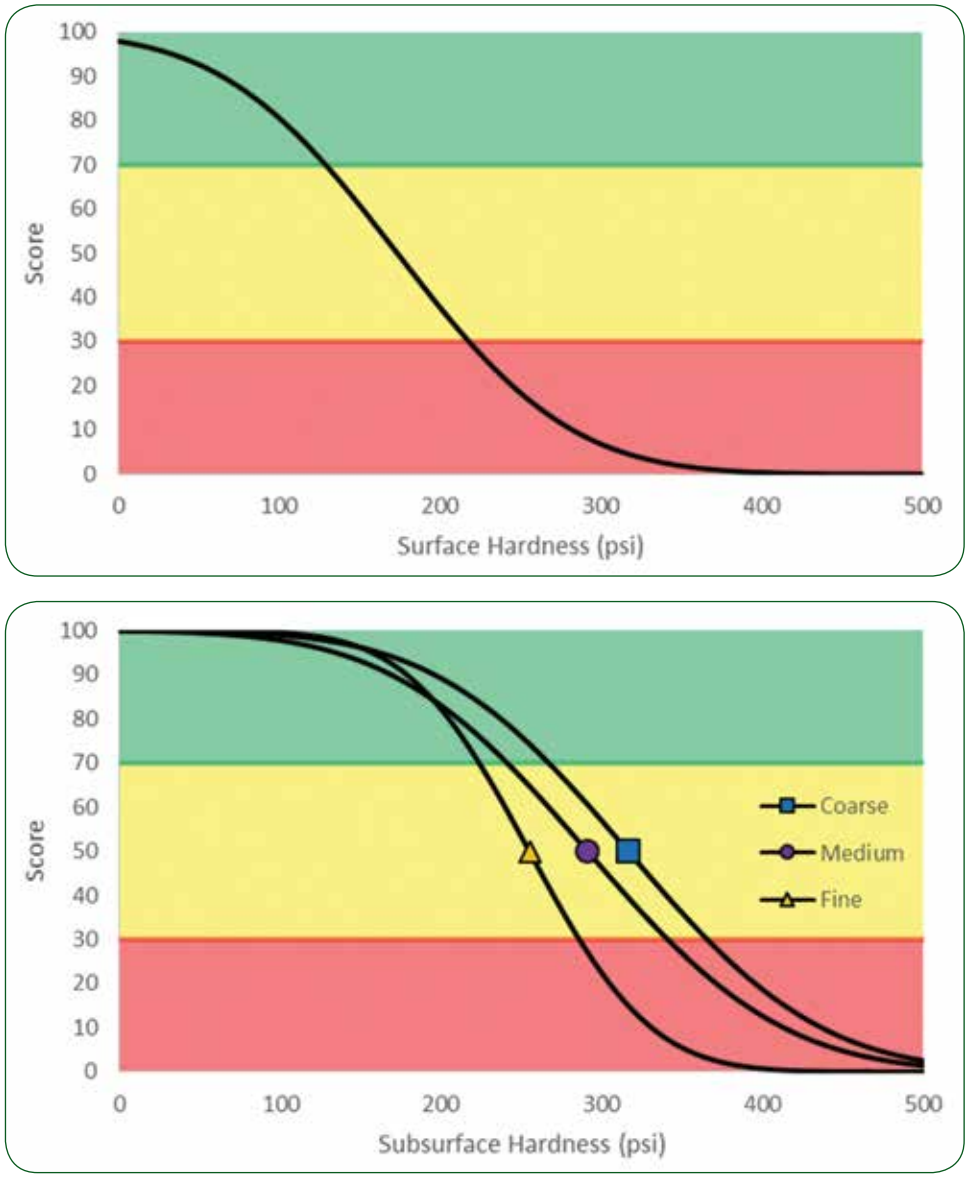

FIGURE 2.23. Scoring function graphs for Surface and Subsurface Hardness for three textural categories. In this case less is better. Higher scores are given to lower values of the indicator.