# ASSESSMENT AND MANAGEMENT OF SOIL HEALTH

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**Concern**
The intensive production of agronomic crops has contributed to reduced soil quality, lower crop productivity and farm profitability. Among the causes are soil compaction, surface crusting, low organic matter, and increased pressure and damage from diseases, weeds, insects, and other pests, as well as a lower density and diversity of beneficial soil organisms. A 2003 survey of 800 New York growers identified soil health as a significant management issue for vegetable systems. These constraints have increased the interest of land managers in assessing the health status of their soils and in implementing sustainable soil management practices.

**Response**
Soil health relates to the re-integration of the physical, biological, and chemical functioning of soils (Figure 1). The Cornell Soil Health Team recently established a standard protocol for soil health assessment based on extensive research that included long-term field experiments and growers' fields in New York. Samples were collected from field crops and vegetable systems and some orchards. It included plow-till and no-till systems, dairy and non-dairy systems, and organic and non-organic farms. This provided the opportunity to assess soil health in NNY under a variety of soil/crop management scenarios. The Cornell Soil Health Team also engaged many growers in discussions on soil health assessment and sustainable soil management, and demonstrated basic concepts during meetings and farm visits. A recent survey indicated that 84% of vegetable growers had gained knowledge on soil health and 81% had changed management practices (tillage, manure and cover cropping practices, etc.) as a result.

The new, inexpensive soil health assessment test is planned to be offered as a for-fee service by Cornell University starting in 2007. We identified important soil health indicators that are relevant for the interpretation of key soil functions in agronomic systems. Out of many potential indicators, we settled on a set of five physical, four biological, and 10 chemical soil properties (Figure 2). This led to the development of the Tier I Soil Health assessment protocol. We used these Tier I indicators to assess the state of soil health in many fields in New York. In this presentation, we will discuss the basics of soil health management, the soil health indicators (Figure 2), sampling methodology (Figure 3), assessment methods, soil health test reports (Figures 4 and 5), and interpretation of those reports. In addition, we will discuss specific examples of soil health reports and management approaches to improving soil health (Figure 6).

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**Figure 1. The soil health paradigm.**
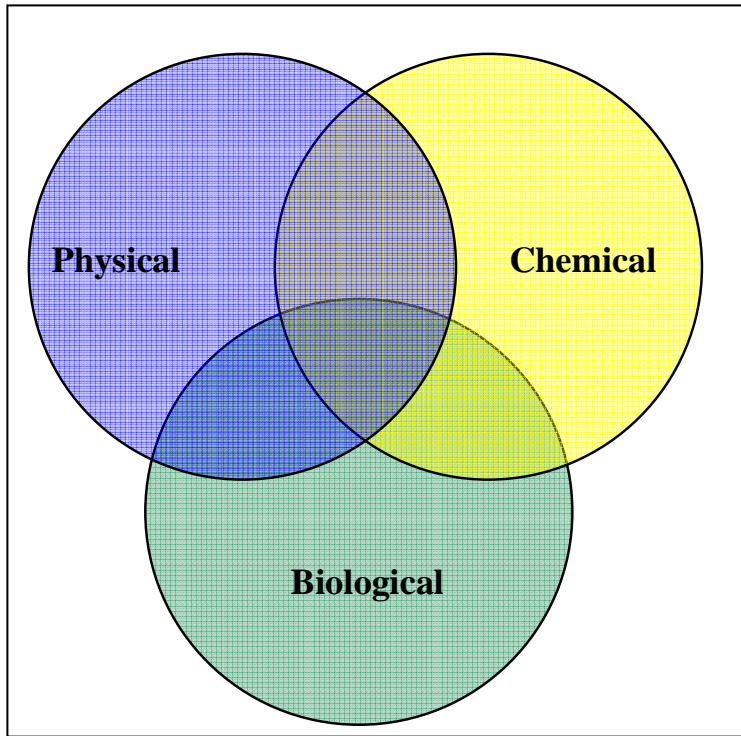


**Fig. 2. Soil health indicators for the Tier-1 soil health test.**

| Soil Indicator | Soil Process (Function) |
|---|---|
| Soil Texture | all |
| Aggregate Stability | aeration, infiltration, shallow rooting, crusting |
| Available Water Capacity | water retention |
| Bulk Density | rooting, water transmission |
| Soil Strength (penetrometer) | rooting at depth |
| Organic Matter Content | energy/C storage, water and nutrient retention |
| Active Carbon Content | organic material to support biological functions |
| Potentially Mineralizable Nitrogen* | N supply capacity |
| Root Rot Rating * | soil-borne pest pressure |
| pH | toxicity, nutrient availability |
| Extractable P | P availability, environmental loss potential |
| Extractable K | K availability |
| Minor Element Contents | micronutrient availability, elemental imbalances, toxicity |

\* Tier 1-PLUS only

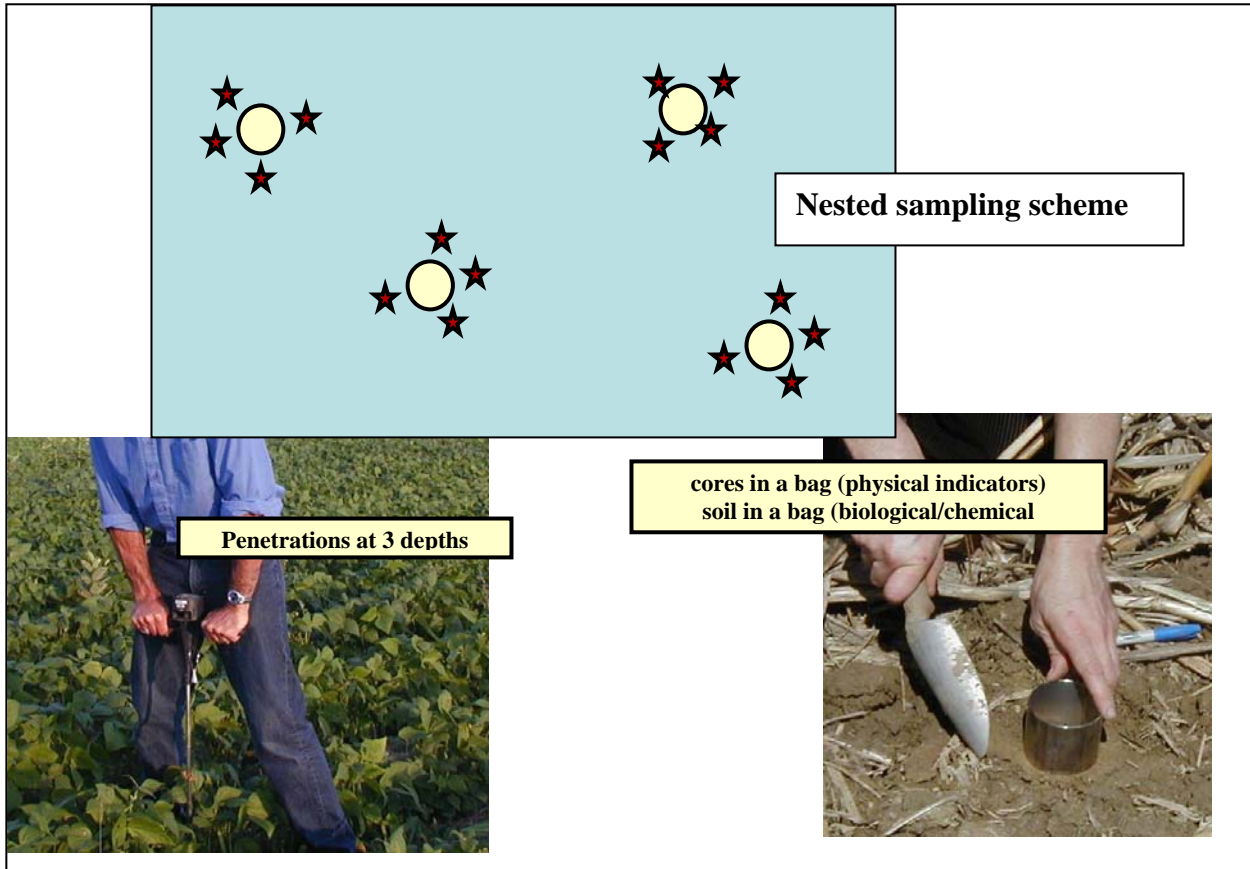**Figure 3. Field sampling scheme for Tier-1 soil health test.**



Nested sampling scheme

Penetrations at 3 depths

cores in a bag (physical indicators)
soil in a bag (biological/chemical

**Figure 4. Soil health report for a vegetable farm under plow till.**

| CORNELL SOIL HEALTH TEST REPORT | | | | | | |
|---|---|---|---|---|---|---|
| **FARMER'S NAME:** | | | **E-MAIL:** | | **Tel:** | |
| **ADDRESS:** | | | | | **Agent:** | |
| **FARM:** | **FIELD/TREATMENT: PLOW TILL** | | **SOIL TYPE:** | **DATE:** | | **SLOPE:** |
| **TILLAGE: 2004: 2005: 2006:** | | | | **DRAINAGE:** | **SOIL TEXTURE:** | |
| **CROP: 2004: 2005: 2006:** | | | | **PERCENTILE RATING\*** | | |

| | INDICATORS | VALUE | RATING | CONSTRAINT | Worst | 50th Pecentile | Best |
|---|---|---|---|---|---|---|---|
| **PHYSICAL** | Aggregate Stability (%) | 19.4 | 2 | aeration, infiltration, rooting | | | |
| | Available Water Capacity (m/m) | 0.20 | 7 | | | | |
| | Bulk Density (g/cc) | 1.45 | 1 | rooting, water transmission | | | |
| | Surface Hardness (psi) | 222 | 1 | rooting, water transmission | | | |
| | Subsurface Hardness (psi) | 292 | 2 | Subsurface Pan/Deep Compaction | | | |
| **BIOLOGICAL** | Organic Matter (%) | 3.3 | 1 | energy storage, C sequestration, water retention | | | |
| | Active Carbon (ppm) | 555 | 3 | | | | |
| | Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week) | 4.0 | 2 | N supply capacity, N leaching potential | | | |
| | Root Health Rating (1-9) | 5 | 5 | | | | |
| **CHEMICAL** | pH (see attached CNAL Report) | 7.2 | 10 | | | | |
| | Extractable Phosphorus (see attached CNAL Report) | 11 | 10 | | | | |
| | Extractable Potassium (see attached CNAL Report) | 63 | 10 | | | | |
| | Micronutrients (see attached CNAL Report) | ADEQUATE | 10 | | | | |
| **OVERALL QUALITY SCORE (out of 100)** | | | **INADEQUATE** | | **48.8** | | |

**Figure 5. Soil health report for a vegetable farm after two years of cover cropping.**

| CORNELL SOIL HEALTH TEST REPORT | | | | |
|---|---|---|---|---|
| FARMER'S NAME: | | | E-MAIL: | Tel: |
| ADDRESS: | | | | Agent: |
| FARM: | FIELD/TREATMENT: VETCH COVER | | SOIL TYPE: | DATE: SLOPE: |
| TILLAGE: 2004: 2005: 2006: | | | | DRAINAGE: SOIL TEXTURE: |
| CROP: 2004: 2005: 2006: | | | | PERCENTILE RATING* |

| | INDICATORS | VALUE | RATING | CONSTRAINT | Worst   50th Pecentile   Best |
|---|---|---|---|---|---|
| **PHYSICAL** | Aggregate Stability (%) | 20.8 | 3 | | |
| | Available Water Capacity (m/m) | 0.21 | 8 | | |
| | Bulk Density (g/cc) | 1.41 | 1 | rooting, water transmission | |
| | Surface Hardness (psi) | 222 | 1 | rooting, water transmission | |
| | Subsurface Hardness (psi) | 292 | 2 | Subsurface Pan/Deep Compaction | |
| **BIOLOGICAL** | Organic Matter (%) | 3.8 | 3 | | |
| | Active Carbon (ppm) | 637 | 5 | | |
| | Potentially Mineralizable Nitrogen (µgN/ gdwsoil/week) | 6.2 | 5 | | |
| | Root Health Rating (1-9) | 6 | 5 | | |
| **CHEMICAL** | pH (see attached CNAL Report) | 7.0 | 10 | | |
| | Extractable Phosphorus (see attached CNAL Report) | 11 | 10 | | |
| | Extractable Potassium (see attached CNAL Report) | 71 | 5 | | |
| | Micronutrients (see attached CNAL Report) | ADEQUATE | 10 | | |
| **OVERALL QUALITY SCORE (out of 100)** | | MEDIUM | | 52.3 | |

**Figure 6. Suggested management approaches to soil constraints identified by the Cornell Soil Health Test.**

- **LOW AGGREGATE STABILITY:**
  o short-term: integrate shallow-rooted cover or sod-rotation crops, add manures.
  o long-term: reduce tillage intensity

- **LOW AVAILABLE WATER CAPACITY:**
  o short-term: add stable organic matter (e.g. compost)
  o long-term: reduce tillage intensity

- **HIGH SURFACE DENSITY:**
  o short-term: localized physical soil loosening
  o long-term: integrate shallow-rooted cover or rotation crops; avoid traffic on wet soils; use controlled traffic lanes

- **HIGH SUB-SURFACE HARDNESS:**
  o short-term: targeted physical soil loosening at depth (e.g., zone building, ripping, strip tillage); integrate deep-rooted cover crops
  o long-term: avoid moldboard plows and disks that generate tillage pans; reduce equipment loads; avoid heavy equipment traffic on wet soils

- **LOW ORGANIC MATTER and LOW ACTIVE CARBON:**
  o short –term: integrate cover or sod rotation crops; add manure or compost
  o long-term: reduce tillage

- **LOW POTENTIALLY MINERALIZABLE NITROGEN:**
  o short-term:  add N-rich organic matter (not excessive); use leguminous cover or rotation crops
  o long-term: reduce tillage

- **HIGH ROOT ROT RATING:**
  o use proper rotations, cover crops and/or appropriate chemical and biological control products

- **LIMITING LEVELS OF pH OR NUTRIENTS:** see CNAL recommendations