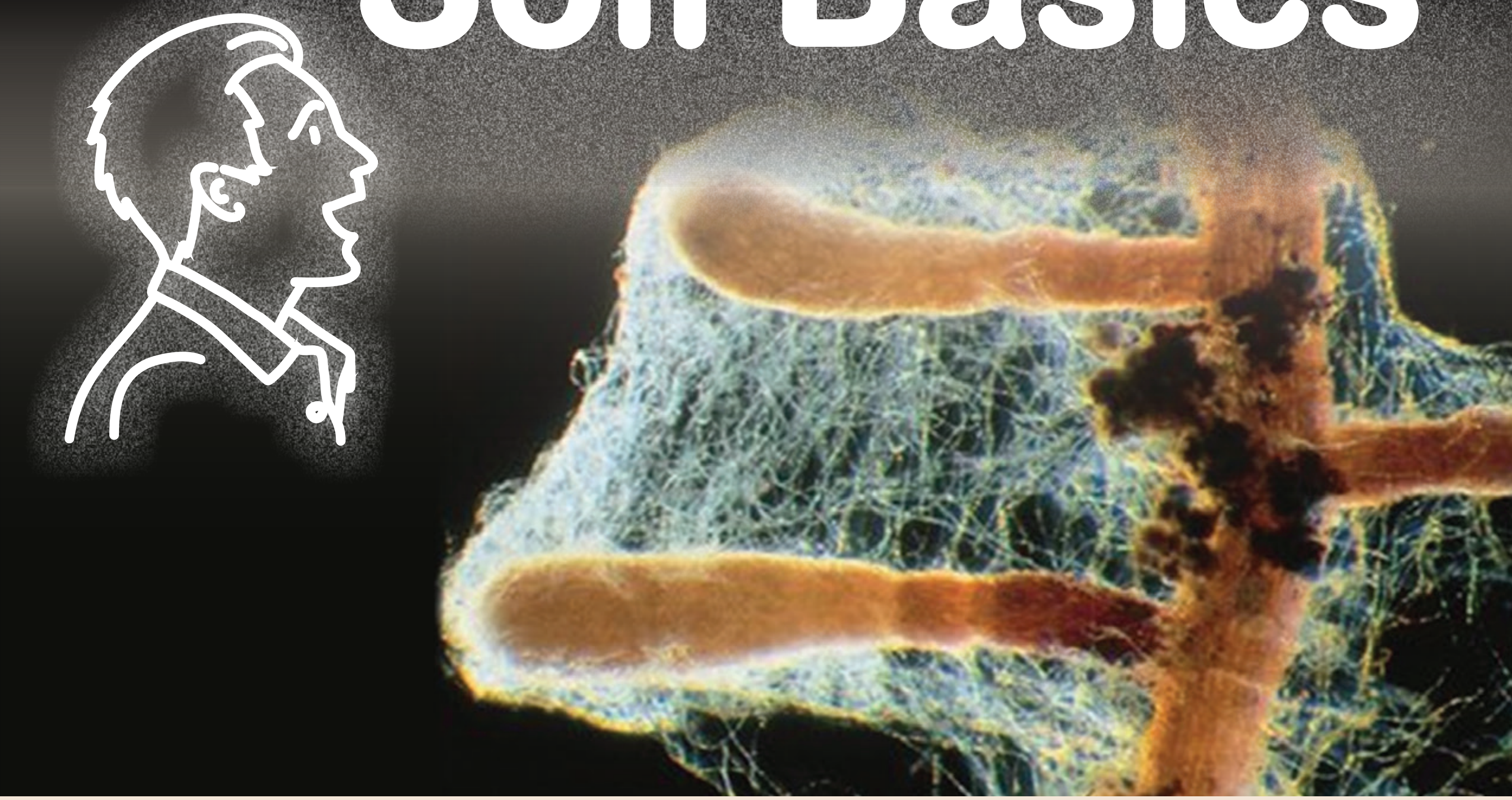
How to Speak Christmas Tree: Soil Basics



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Soils and soil properties form the foundation of managing Christmas tree plantations. It has often been observed that soils are the ultimate resource we manage in any form of plant agriculture, and Christmas tree production is no different. In order to produce a successful Christmas tree crop, growers need to have a solid working knowledge of the soils on their farm. In this edition of 'How to Speak Christmas Tree', we will focus on understanding key terms and concepts related to soils and soil management. Understanding soil principles is especially important in evaluating a site and determining which species are most likely to be successful and in developing a fertilization plan to manage soil and plant nutrients.

What is soil?

Let's start by considering what soil is. Standard definitions of soil typically begin with dense statements about 'the unconsolidated material at the earth's surface, etc.' From a practical standpoint we can consider soil to be a four-part matrix that supports plant roots and plant growth. The four components of soil are mineral soil particles, air, water, and organic matter. Air and water occur primarily in the pore spaces between soil particles; these are important for overall plant function as plants obtain necessary water from the soil and roots use oxygen from the air for respiration. Mineral soil particles are defined based on their size as sand, silt, and clay. The organic or biological component of soils includes living organisms (e.g., bacteria, fungi,

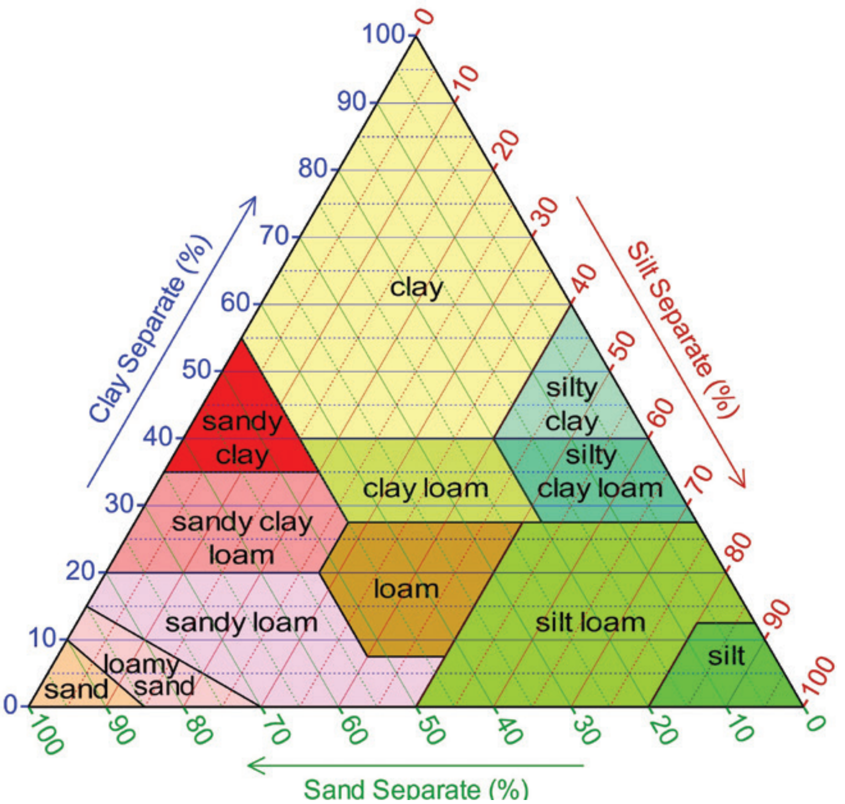

Figure 1. Soil texture triangle. Source: U.S. Department of Agriculture.

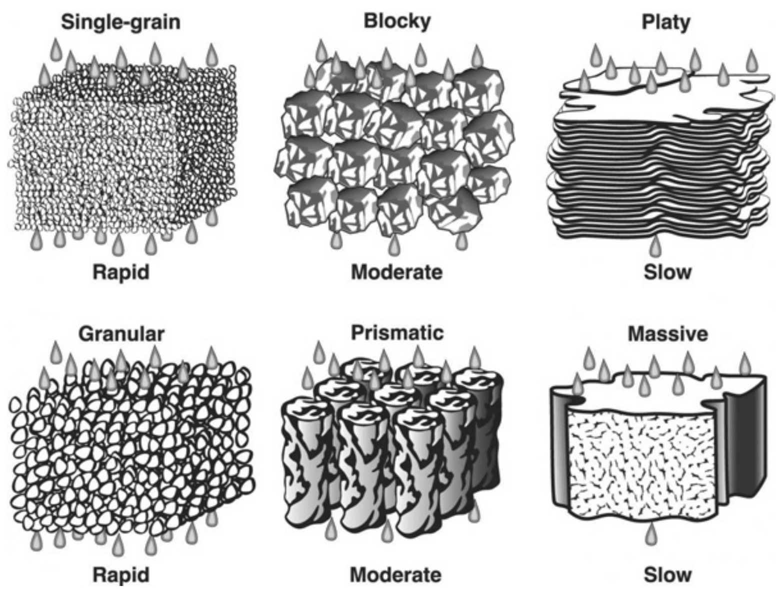

Figure 2. Examples of soil structure. Source Ohio State University.

earthworms) or once-living material in various stages of decomposition. The type and amount of these components determine whether and how well plants, including Christmas trees, can grow. We can characterize the effects of these components based on soil physical properties and soil chemical properties.

Soil physical properties

Soil texture refers to the amount of sand, silt, and clay in a soil. Discussions of soil properties invariably begin with soil texture because of its overriding importance on other important properties of soil. Commercial soils labs can determine soil texture through ***particle size analysis*** (also referred to as mechanical analysis or texture analysis). Using the percent sand, silt, and clay from a particle size analysis, we can determine the textural class of a soil using the soil texture triangle (Fig. 1). While there is no single 'ideal' soil texture, loam soils that include a mixture of sand, silt, and clay are preferred as sand particles help to provide porosity and drainage while clay increases moisture and nutrient-holding capacity of soils (more on this below).

Soil structure refers to the capacity of soil particles to form aggregates. Unlike other soil properties that can be quantified, soil structure is a qualitative trait, and soils can be described as granular (single grained), aggregated, columnar, and so forth (Fig. 2). Good soil structure is important for soil permeability to water and air. From a practical standpoint, soil structure is important because it can be adversely affected by excessive tillage, which can result in erosion or reduced permeability.

Bulk density, as the term implies, refers to the density of soil and is calculated as the dry weight of soil divided by the volume. Bulk density is important because it provides a measure of the extent of compaction on soils. In Christmas tree production, traffic from heavy equipment can compact soils resulting in less pore space, which reduces soil aeration, water holding capacity, and the ability of tree roots to penetrate soil.

The ***water holding capacity*** of a soil is determined by the soil texture and amount of pore space in a soil. When all the pore spaces in a soil are full of water, the soil is at the ***saturated water content.*** If the soil is allowed to drain and water held by gravity is removed (i.e., only water held by capillarity remains), the soil is at ***field capacity.*** As the soil continues to dry, eventually the remaining water will be bound so tightly to the soil particles that it will be unavailable to plants. This point is termed the ***permanent wilting point*** and is defined as soil water that is held at 15 bars of tension or greater. Soil scientists define ***plant available water*** as the volume of water between field capacity and permanent wilting point. Very sandy soils have low available water because they have large pores and lose most of their water to drainage via gravity, whereas heavy clay soils can have reduced plant available water because they hold a high proportion of water at high tension that is unavailable to plants (Fig. 3).

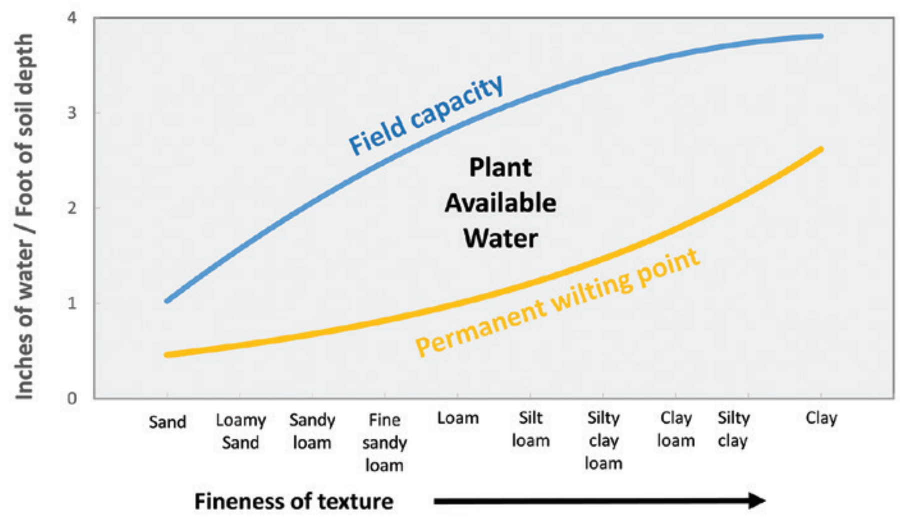

Figure 3. *Effect of soil texture on water holding capacity. Source: Soil Dakota Soil Health Coalition.*

Soil chemical properties

In addition to soil physical properties, several soil chemical properties are important in determining the suitability of soils for Christmas tree production and for managing established plantations to ensure suitable growth rates and good foliage color.

Soil pH refers to how acidic or basic a soil is. pH values range from 0 to 14, with a value of 7 indicating neutral pH, while values below 7 are acidic and values above 7 are basic. In general, most plants grow best at a slightly acidic soil pH, such as 6.5. However, conifers, including many grown for Christmas trees, have adapted to more acidic conditions, and we find that a pH of 6.0 or even a little lower is optimal for tree growth and color. This is due to the availability of key plant nutrients such as manganese and iron, which decline as soil pH increases (Fig. 4). Soil pH is included in most standard soil nutrient tests provided by university or commercial analytical laboratories. Growers can also determine their soil pH on a 1:1 solution of soil and distilled water using litmus paper or a portable pH meter. If using a pH meter, be sure to calibrate the meter using pH standards before using.

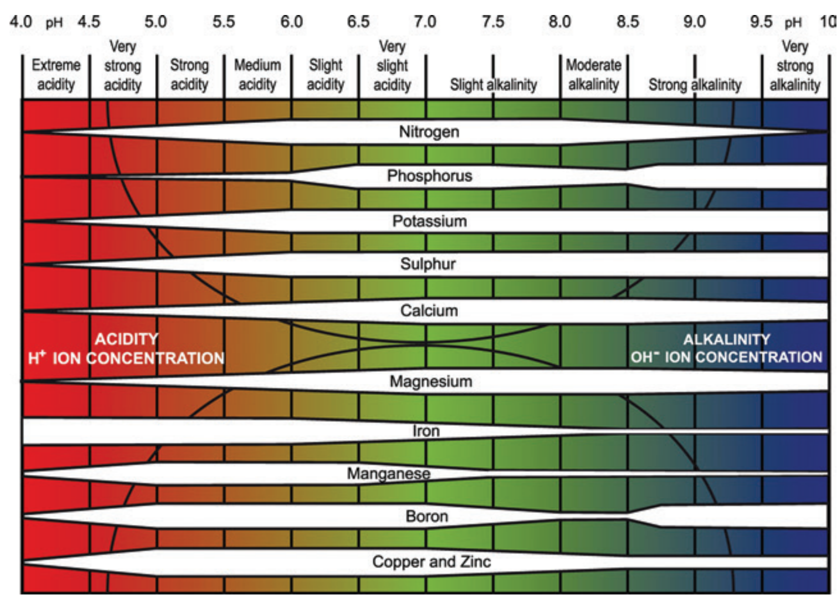

Figure 4. *Effect of soil pH on relative nutrient availability. The width of each bar indicates the relative availability of each nutrient. Source: Potash Development Association.*

The relative ability of a soil to serve as a reservoir for plant nutrients is reflected in the soil ***cation exchange capacity*** or CEC. In order to understand CEC, it is important to note that plant nutrients occur in the soil in a charged, or ionic, form. Large portions of the nutrient elements that are essential for plant growth occur as positively charged forms (cations). Plant nutrients that occur as cations include potassium, calcium, iron, magnesium, copper, zinc, manganese, and nitrogen (as ammonium). Nutrients that occur as cations in the soil are held on clay particles and on organic matter, both of which have negative charges. Therefore, soils that have a clay or clay loam texture or have a high proportion of organic matter will have a high CEC and can retain important nutrients. In contrast, very sandy soils, especially those with low organic matter, have low CEC and growers may need to fertilize more often with smaller amounts to maintain soil fertility.

Soil nutrients

Soil scientists have identified 17 ***essential elements*** that are required for plant growth (see table). Of these, three (carbon, hydrogen, and oxygen) come

Figure 5. *Fine threads of mycelia from mycorrhizae improve the efficiency of plant roots in capturing water and nutrients. Source: Simon Egli, waldwissen.net.*

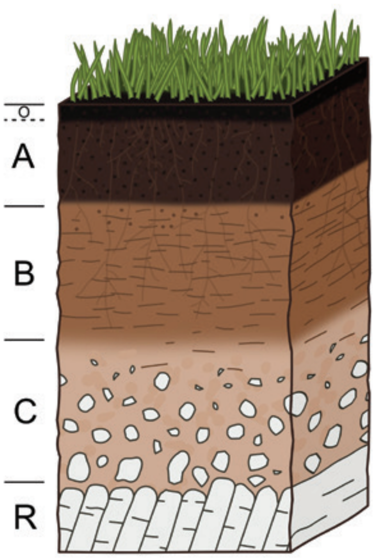

Figure 7. *A soil profile consists of a series of layers (horizons) that result from weathering of parent material and other soil development processes. Source: Soil Science Society of America.*

from air and water. The remaining elements are referred to as ***mineral elements*** (or plant nutrient elements) and occur naturally due to weathering of soil mineral particles or decomposition of soil organic matter. Plant nutrient elements that are required in relatively large amounts are termed ***macronutrients*** and include nitrogen, potassium, phosphorus, calcium, magnesium, and sulfur. Elements that are required by plants in relatively small amounts are referred to as ***micronutrients*** (sometimes referred to as trace elements) and include manganese, copper, zinc, chlorine, molybdenum, iron, boron, and nickel.

Soil biology

Soils are home to a vast array of organisms including bacteria, fungi, and invertebrates such as insects and nematodes. A full discussion of soil biology is far beyond the scope of this article; however, there are several key soil biological processes that influence nutrient availability that growers should be familiar with. ***Mineralization*** is the process by which soil organisms breakdown organic matter and release nutrient elements into forms that can be taken up by plants. ***Nitrification*** is the conversion of nitrogen in the soil, from either fertilizer or mineralization of organic matter, into nitrate. Nitrification is important because nitrate-nitrogen can be taken up by plants, but nitrate has a negative charge so it cannot bind to CEC sites in the soil and is subject to leaching, potentially resulting in a loss of N from the system.

Two important biological processes for plant nutrition involve mutually beneficial interactions between plants and other organisms. Mycorrhizae are beneficial fungi that form a symbiotic relationship with tree roots, including on many conifers grown as Christmas trees. In a mycorrhizal association, the threadlike structures (mycelia) of the fungus improve the ability of the tree to take up water and nutrients from soil, while the fungus receives carbohydrate energy from the tree (Fig. 5). Another important symbiotic relationship is nitrogen fixation in which bacteria form nodules on the roots of certain plants that convert atmospheric nitrogen (N2) into nitrate that can be taken up by plants. Common examples of plants that are able to fix nitrogen are legumes such as clover, alfalfa, and soybeans. Using N-fixing plants as cover crops in between or during tree crop rotations can provide a means to add organic matter and nitrogen to plantations.

Getting information about your soils

The USDA Natural Resource Conservation Service ***Web Soil Survey (WSS)*** is useful for quickly providing general information on soils. This interactive on-line tool allows growers to access a wealth of information on their fields or on sites they are considering to acquire or lease. Using WSS, users can zoom in on their fields and specify an Area of Interest (AOI) such as areas they are considering for planting (Fig. 6). The tool provides maps of the soil series in the designated area. The program will also provide general information on properties such as soil texture and soil drainage class. The latter is especially useful as many conifers used as Christmas trees are sensitive to poor soil drainage. The WSS also provide information on layers within soil profile within a given soil series. The ***soil profile*** is layers or horizons that occur in a given soil and result from weathering and other soil development processes (fig. 7). Soil

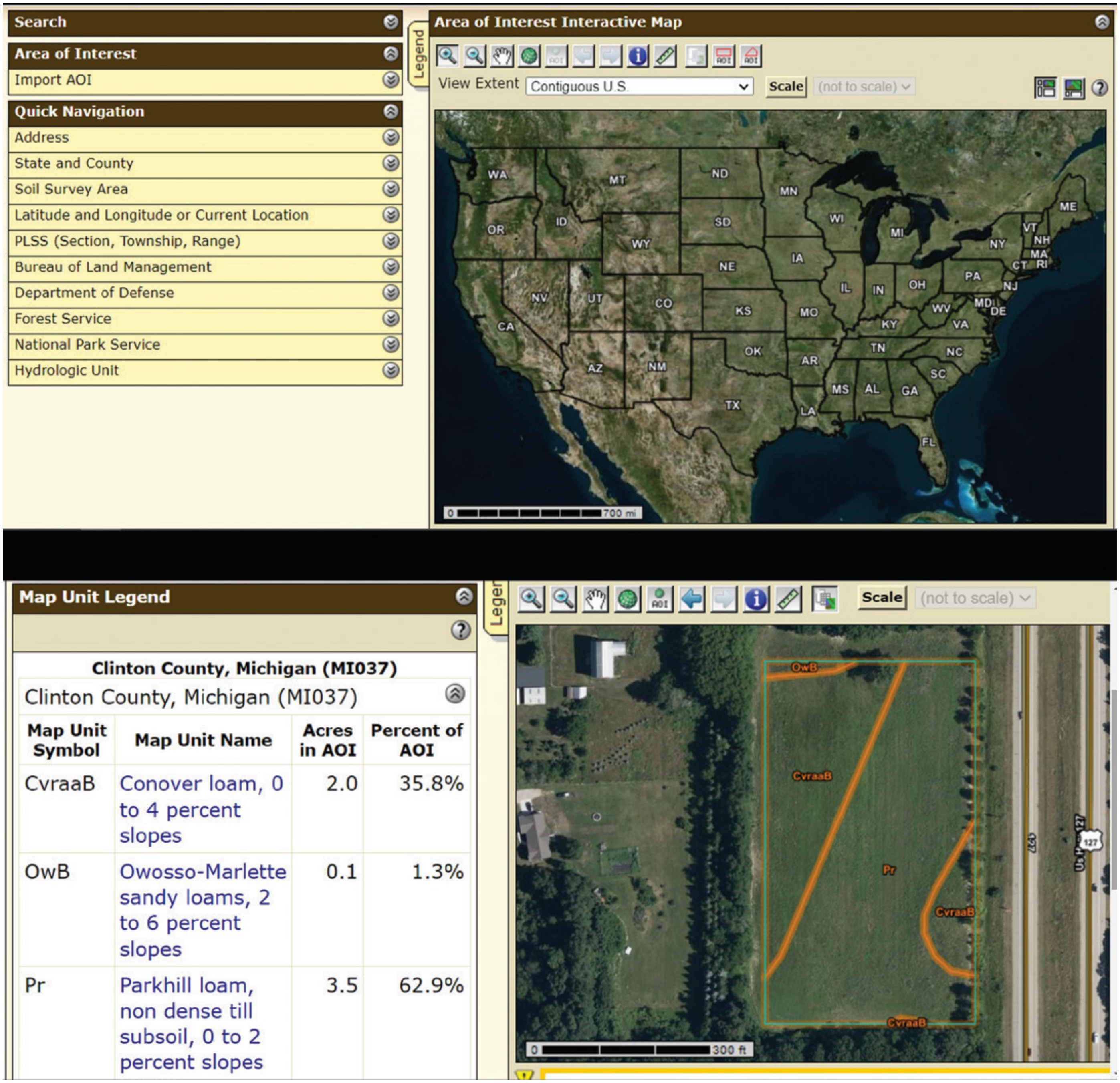

Figure 6. *The USDA Web Soil Survey allows users to zoom in to a specific area of interest (AOI) and find soils information for their location. Source: USDA NRCS.*

typically have an 'O' or organic horizon (humus) at the surface, underlain with an 'A' horizon (topsoil) that contains parent material and organic matter. Beneath the A horizon is the 'B' horizon (subsoil), which can contain nutrients leached from the surface horizons. Soils also contain a 'C' horizon of parent from which the soil developed and then ultimately bedrock (R).

Soil testing

In order to get information that is specific to the soils on their sites, growers can collect soil samples and send them to university or private soil testing labs (Fig. 8). Common soil tests include particle size analysis to determine soil texture and soil nutrient analyses. Most soil nutrient tests will include soil concentration of macronutrients (P, K, Mg, S, Ca) and key micronutrients (Mn, Fe). Note that nitrogen is not included in standard soil tests because it is highly dynamic in soils, making soil tests of N of limited value to fertilizer decisions in most cases. Most standard soil tests will also include soil pH and soil CEC. Many tests will also provide buffer pH, which is a measure of the capacity of a soil to

Essential Elements for plant growth

Element	Chemical Symbol	Notes/function
Carbon	C	From air
Hydrogen	H	From water
Oxygen	O	From air
	Macronutrients	
Nitrogen	N	Amino acids, proteins
Phosphorous	P	Energetic reactions, DNA, RNA
Potassium	K	Water relations, cold hardiness
Sulfur	S	Amino acids, chlorophyll formaion
Magnesium	Mg	Component of chlorophyll
Calcium	Ca	Cell wall synthesis
	Micronutrients	
Iron	Fe	Chlorophyll synthesis
Manganese	Mn	Co-factor and catalyst
Boron	B	Cell wall formation, membrane integrity
Zinc	Zn	Component of enzymes
Chlorine	Cl	Water relations, disease resistance
Molybdenum	Mo	Protein synthesis
Copper	Cu	Enzyme activation
Nickel	Ni	Nitrogen metabolism

resist changes in pH and is used by labs to determine liming recommendations when raising soil pH is desired. Growers are encouraged to contact the lab they plan to use prior to sampling to get specific instructions on sampling, handling, and shipping procedures, as well as costs for testing. Contact your local university extension office for details on soil sample labs in your area.

Figure 8. *Collecting soil samples for testing at an analytical laboratory. Photo: BertCregg.*