1. The Nature of Soils and Soil Fertility

The Ontario *Soil Fertility Handbook* contains information on the fundamental concepts of soil fertility. If you have ever wondered how nutrients make their way to plant roots or why different soils vary in pH, the answers can be found within these pages. You can also find practical information in areas such as proper soil sampling techniques, soil test interpretation and fertilizer application methods.

Soil fertility is the ability of a soil to supply essential plant nutrients in adequate amounts and proportions for plant growth and reproduction. The physical nature and properties of a soil — including texture, porosity and mineral makeup — determine its inherent fertility. In this introductory chapter, we will explore these fundamental soil properties and consider the impact they have on productivity.

Soil horizons

Every soil has a profile – a series of layers from the surface to the parent material. These layers are called “horizons” and are designated by the letters A, B and C (see Figure 1–1).

The A horizon, or topsoil, is an organically enriched layer that contains the greatest proportion of plant roots. It is the zone in which organic matter accumulates. In Ontario’s mineral soils, uncultivated topsoil depth is typically no greater than 30 cm (12 in.).

The B horizon is hidden from sight but has a large impact on important soil properties such as drainage. Materials such as iron and aluminum oxides, as well as clays, accumulate in the B horizon over time. The B horizon, or subsoil, contains less organic matter than the topsoil but typically has a higher proportion of small pores and may store a large portion of the water required for plant growth.

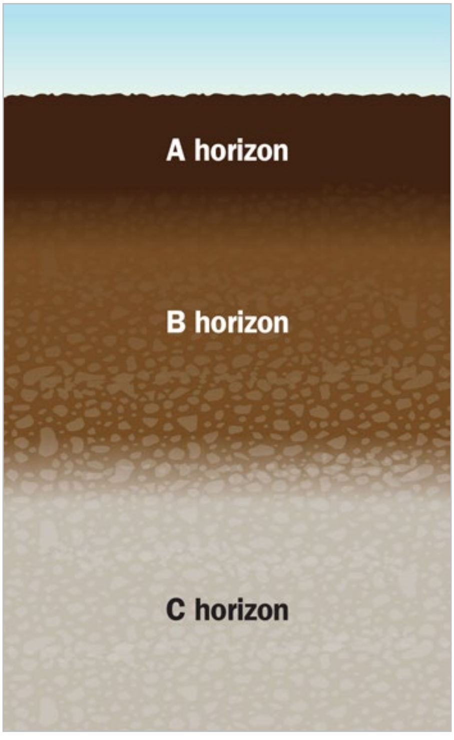

Figure 1–1. Generalized soil profile

The C horizon is parent material — the material from which the soil formed. In Ontario, the parent material could be anything from till to sand to a highly productive wind-blown material called loess. Much of the parent material in southern Ontario is till, deposited by the retreat of glaciers approximately 10,000 years ago.

Soil components

Soils are comprised of four main components. Often the ideal topsoil is shown as containing roughly 25% water, 25% air, 45% minerals and 5% organic content by volume (see Figure 1–2). In reality, these proportions vary widely depending on both soil type and management history, which in turn greatly affect a soil's productivity.

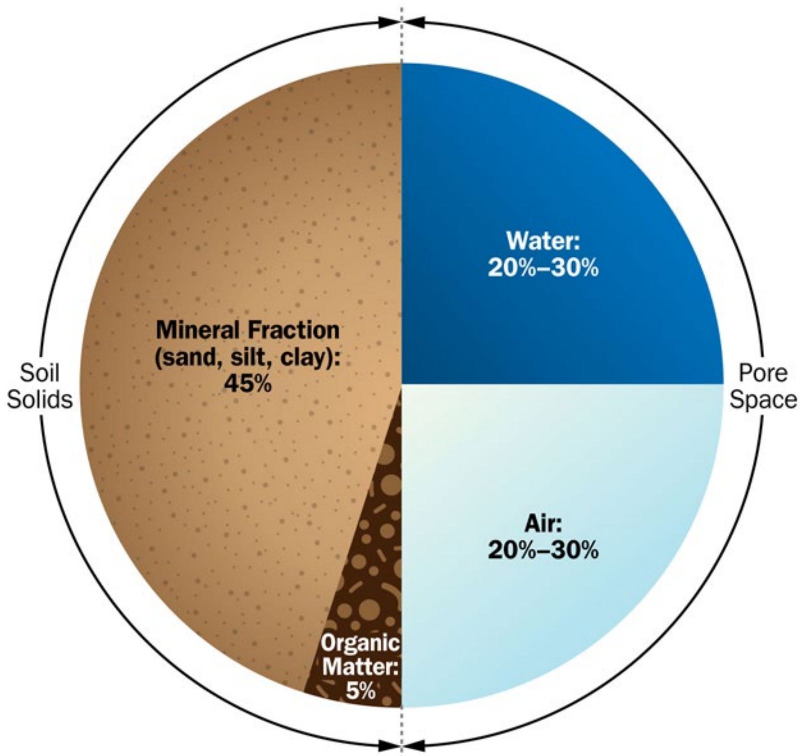

Figure 1–2. Components of an ideal soil, by volume

Soil components of minerals, water, air and organic matter interact to cycle and supply plant available nutrients. Biological and biochemical reactions occur constantly in soil, which help to replenish nutrients in response to plant uptake. All components — minerals, water, air and organic matter — are essential for this process to take place. In agricultural production, the objective is to maintain effective nutrient cycling and the soil's capacity to meet the nutrient requirements of plants (*The Nature and Properties of Soil, 15th edition*, Brady and Weil).

Soil minerals

All soils contain sand, silt and clay. Primary minerals include those that are found in sand and silt and closely resemble the materials from which they formed. Secondary minerals form from the weathering of primary minerals. An example is silicate clay, which has a high surface area and is negatively charged.

The proportion of sand, silt and clay depends on the soil's parent material and determines a soil's texture. Soil texture is an inherent property that cannot be changed. It plays an essential role in determining water drainage and availability, as well as the capacity of a soil to hold onto and exchange nutrients.

Soil water

Nutrients must be taken up by plants from soil water (also referred to as the soil solution), which is constantly drawn from and replenished. An excess of water, however, limits root nutrient uptake. Insufficient water, on the other hand, limits nutrient movement toward roots (see Figure 1–3). This will be discussed in Chapter 2 in terms of nutrient uptake pathways.

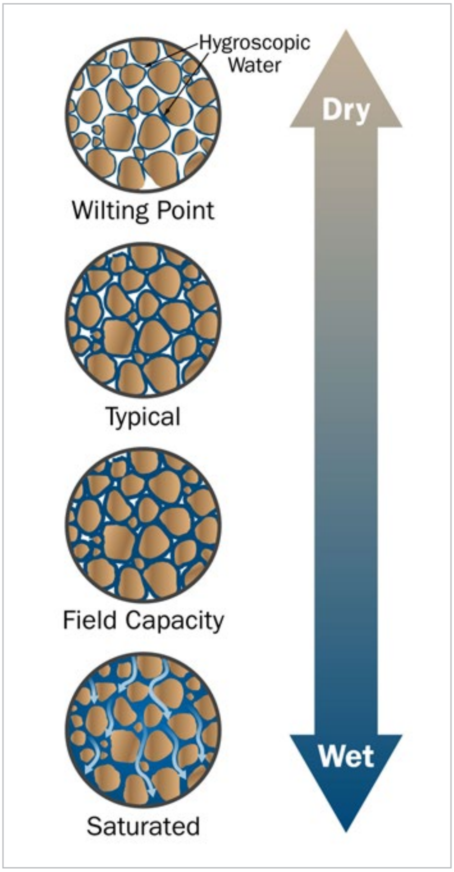

Figure 1–3. Soil water status across a range of moisture conditions. Downward arrows indicate drainage water.

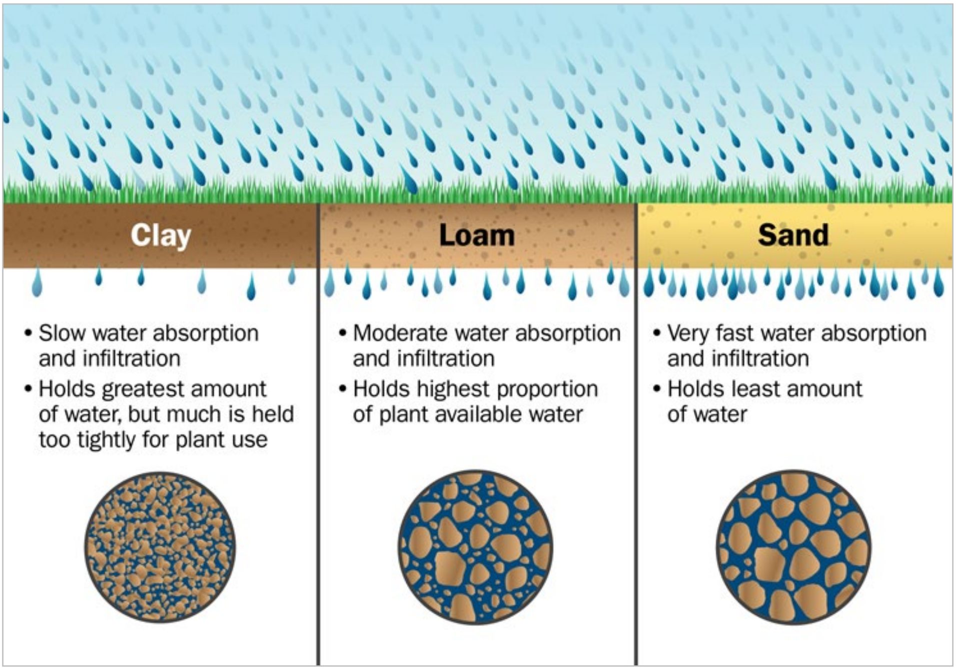

Figure 1–4. Drainage and water-holding characteristics of major soil textural classes

A soil's ability to hold water can be thought of as that of a sponge. After being saturated, water in soil will drain from the largest pores. It is held within smaller pores, where attraction with soil limits movement. A soil's texture and the type and proportion of its pores determine its ability to both drain and hold onto water (see Figure 1–4):

- A soil with a high percentage of large pores, such as a sand, will drain a relatively large amount of water quickly due to gravity.
- A clay soil, which contains many small pores and few large pores, will drain much less water and do so more slowly.
- An ideal soil is a well-structured medium-textured soil, which drains water adequately but also provides an ample amount of plant available water.

Soil air

Under moist but not saturated conditions, air occupies approximately 50% of the total pore space in an ideal soil. Soil aeration is critical — for gas exchange, root growth and soil life. When water drains after a rainfall, large pores become filled with air.

Air in soil is different from air in the atmosphere. It is generally quite humid and has a much higher carbon dioxide content, which is the result of the activity of soil organisms and plant roots.

A well-structured medium-textured soil provides an ideal proportion of pore sizes for aeration in both wet and dry conditions. Coarse-textured soils tend to have a large proportion of air-filled pores. This allows for excellent gas exchange and root growth but can result in drought stress if rainfall is inadequate. The high percentage of small pores in fine-textured soils can result in low oxygen conditions during periods of high rainfall and also increase the risk of nitrogen loss through the process of denitrification.

Soil organic matter

Soil organic matter includes all carbon-containing materials in the soil. It is made up of microbial, plant and animal life at various stages along the spectrum of alive and intact to long-dead and decomposed. Though it is present in a relatively small quantity, organic matter has a large effect on almost all soil properties. Organic matter stores and supplies nutrients, improves soil structure and water infiltration, supports soil biological activity and buffers against changes in soil pH. You can learn more about organic matter and its role in soil fertility in Chapter 2.

Interaction of soil components

Soil fertility encompasses much more than just soil test values. The physical condition and quality of a soil, as affected by long-term management, have a profound effect on the supply of plant-available nutrients and the crop's ability to access these nutrients. So too does the soil's biological activity. The information found within this handbook is essential for sound management of nutrients in agricultural soils. It is most effectively applied in conjunction with best management practices that maintain or improve soil health over the long term.

> "Healthy soils function more efficiently with less need for expensive human interventions and inputs than unhealthy and degraded soils." – page 48, *The Nature and Properties of Soils*, *15th edition*, Brady and Weil.