Best Management Practices

DROUGHTINESS

Droughtiness relates to the moisture conditions of the soil. A droughty soil exhibits chronic evidence of a moisture deficit for crop growth.

In a droughty soil, moisture inputs (e.g., rainfall) and pre-existing available moisture levels cannot meet evapotranspiration rates, i.e., the rate at which water is evaporated from cropland and plant surfaces plus the amount of water transpired by the growing crop. Basically, there is less water being supplied to a crop than what the crop requires to grow.

This infosheet describes a set of diagnostic tools used to describe the type, nature and extent of droughtiness in Ontario cropland soils. Proper diagnosis is essential to identify the most suitable best management practices (BMPs) for a given field.

THE ROLE OF HEALTHY SOIL IN A CHANGING CLIMATE

Agriculture and climate are directly linked – anything that has a significant effect on our climate will influence farm production. Greenhouse gas (GHG) emissions and climate change are global concerns, and agriculture can be part of the solution.

BMPs that improve soil health can also help lower GHG emissions, reduce phosphorus loss from fields to surface water, and improve resilience to drought or excessively wet conditions. Healthy soil – an essential component of a healthy environment – is the foundation upon which a sustainable agriculture production system is built.

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Droughtiness and Soil Health

Droughty soils can be recognized by crop performance and crop condition on fields and within fields during low water periods. Crops will display uneven emergence or show signs of moisture stress (e.g., wilting) through the growing season during periods of low rainfall and in the same parts of the field each year.

Soils are either inherently droughty due to natural soil properties (e.g., texture, textural layers within a soil profile, shallow profile) or become droughty due to poor soil management practices (e.g., plow pan, compaction).

Soils that are typically droughty are usually:

- coarse-textured (sandy, gravelly)
- located in upper-slope or crest-landscape positions
- without any water table activity within the top 1 m (3 ft) of the soil
- shallow to bedrock

These characteristics are found in sand plains, gravel ridges and bedrock-controlled landscapes. When referring to soil information from soil maps and reports, the natural soil drainage classes for these soils are usually referred to as “rapid” or “very rapid” drainage. On older maps and old soil reports they are referred to as “excessively drained.”

Soils that have become droughty due their current condition (i.e., degraded) may have been:

- compacted — plow pans can reduce permeability, cause shallow rooting, and display drought characteristics during low water conditions.
- eroded — where the subsoil or parent material exposed at the surface (e.g., by wind, water or tillage) has both poor infiltration rates and high runoff. Moisture can't be replenished, or the soils have higher infiltration and percolation rates and low moisture-holding capabilities (e.g., eroded loam topsoil exposing a gravelly parent material).

In bare soil conditions, droughty soils are more prone to wind and water erosion than soils with higher moisture-holding capacities.

Drought-stressed plants do not use nitrogen (N) fertilizer or other crop inputs efficiently. This can lead to visible nutrient deficiencies, reduced crop growth and poor yields.

Crops growing on compacted soils can have shallow rooting systems and suffer from moisture deficit. Compacted headlands often show these signs well before the rest of the field.

Droughty soils often have high percolation rates. Salts in soil solution can move quickly through soils. Nitrate, a highly soluble crop nutrient in a salt form, is prone to leaching on porous, highly permeable (droughty) soils. High nitrate levels in groundwater can pose health risks to people and livestock.

Coarse-textured soils lose moisture quickly at the surface, making them easily eroded during wind events. If not properly managed, crops can be seriously damaged from sand blasting or from being buried by drifting soil.

Droughtiness: The Basics

To understand how droughty soils function and how to manage them more effectively, it's helpful to understand the principles of soil water, groundwater and the conditions that lead to droughtiness.

INFILTRATION

Infiltration is the process by which water enters the soil surface and displaces air. The rate of infiltration is directly related to local topography, surface soil properties and site conditions. Infiltration rates are higher in soils with large pores and aggregates, and when covered with forage, crop residues or a cover crop. Conversely, bare soils with small pores (e.g., fine materials) and poor seedbed conditions have low infiltration rates. Some soils such as silty and clayey soils have inherently low infiltration rates.

High infiltration rates do not necessarily lead to droughty soils unless the water moves quickly out of the rooting zone.

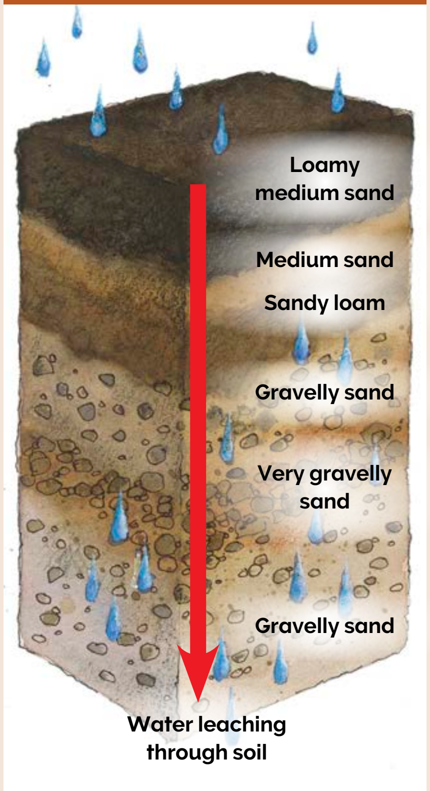
HYDRAULIC CONDUCTIVITY

Once water moves into the soil, gravity helps it move from near the surface down through the soil profile. "Hydraulic conductivity" is the term used to describe the rate at which water passes through (permeates) the soil. This rate is linked to porosity, texture, structure, depth to restricting (e.g., compacted) layer, and depth to water table.

Soils that are highly permeable and suffer from chronic droughtiness are those with:

- large cracks and continuous large pores (macropores)
- coarse or sandy soil materials (texture), or
- a high percentage (>33%) composition of coarse fragments (e.g., gravels, stones, etc.)

WATER MOVEMENT IN SOIL



Soils with high hydraulic conductivity are sometimes described as permeable soils or having high permeability.

The concept of hydraulic conductivity is captured in the classification system used to describe natural soil drainage in the field. Soils that are rapidly drained are sandy, highly porous, and have no restricting layer or evidence of a soil water table within 1 m (3 ft) of the soil surface (right photo). These soils often have droughtiness issues. Poorly drained soils have a high (shallow) water table and are usually less porous than rapidly drained soils (left photo). The soil drainage classification system is used to describe soil moisture conditions in soil survey maps and reports. There are seven soil drainage classes — from very rapid to very poor.

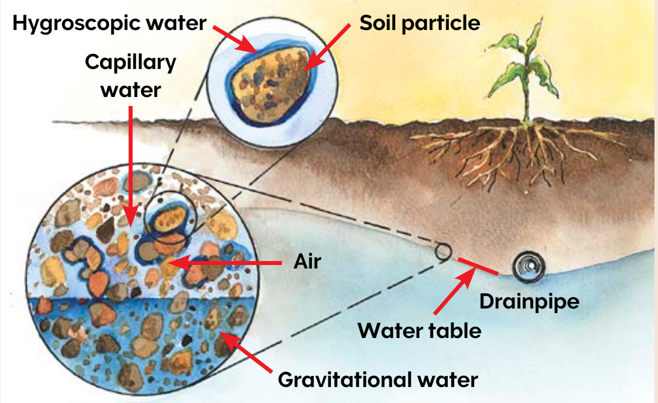
SOIL WATER

Not all soil water is equal. Some is held so tightly that it is virtually unavailable to plants. Other soil water flows freely and isn't held in the soil. The amount of soil water is critical for crop uptake and metabolic requirements, as well as temperature, workability, soil aeration and crop root exploration.

Soil water can be classified as gravitational, capillary, or hygroscopic.

Gravitational water — water that moves through soil due to gravitational forces. It is the portion of soil water in excess of capillary and hygroscopic water. Gravitational or drainage water fills cracks and large pores in the soil. Held by tension much like a sponge, water will not drain (i.e., move by gravity) until the soil has reached a maximum capacity for capillary water.

SOIL WATER



There are three types of soil water: gravitational (excess water), capillary water (available to plants), and hygroscopic water (held tightly by soil particles).

Capillary water — the part of soil water held cohesively as a continuous layer around particles and in spaces, most of it being available to plant roots. Crops can only use soil moisture in a certain range of water volume and tension. Only capillary water is available to the crops.

There is very little capillary water in droughty soils.

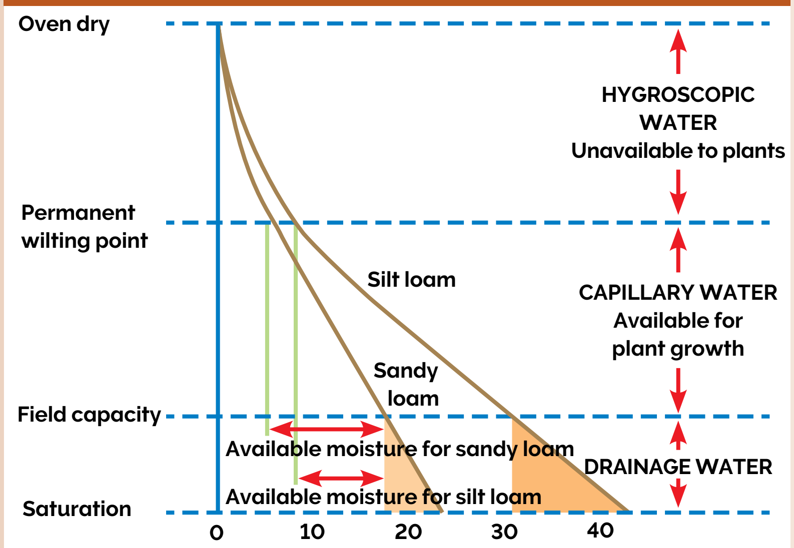
The amount of available (capillary) soil water closely follows soil texture:

- Loams, silt loams and clay loams can hold the most available water.
- Clay soils have high surface areas and many fine pores, resulting in the highest proportion of hygroscopic water — but it is unavailable to plants.
- Sandy soils are dominated by gravitational water, as soil pores are too large for much capillary flow and the charge and area of particle surfaces are limited.

Hygroscopic water — water held within 0.0002 mm of the surface of a soil particle. Hygroscopic water is held too tightly to be accessible to plants. This water is essentially non-mobile and can only be removed from the soil through heating. If the only soil water left in a dry soil is hygroscopic, the crop will suffer extreme drought symptoms and the plants roots will reach a soil moisture content referred to as the permanent wilting point. There is a higher proportion of hygroscopic water in droughty soils.

Silt loam soil has a higher overall porosity and a higher proportion of medium- and fine-sized pores compared to a sandy loam. As seen from the chart above, the silt loam has a higher moisture percentage (30%) at field capacity than the sandy loam (20%). The silt loam will also have a greater range of plant-available moisture between the permanent wilting point (8%) and field capacity (30%) compared to the sandy loam (5–20%). %). If the only soil water left in a dry soil is hygroscopic, the crop will suffer extreme drought symptoms and the plants roots will reach a soil moisture content referred to as the permanent wilting point.

SOIL WATER CHARACTERISTICS FOR TWO SOILS



CAPILLARY ZONE

Soil above the water table is unsaturated, as all gravitational water has moved out of the pores. But it's not dry. There is a zone above the water table that contains moist soil, known as the "capillary zone." As crops use the available water, more water is drawn up from the water table through the capillary action.

In droughty soils, the capillary zone is often too deep to be accessed by growing crops. This is due to the depth to water table and the relatively minimal capillary action on coarse-textured soils.

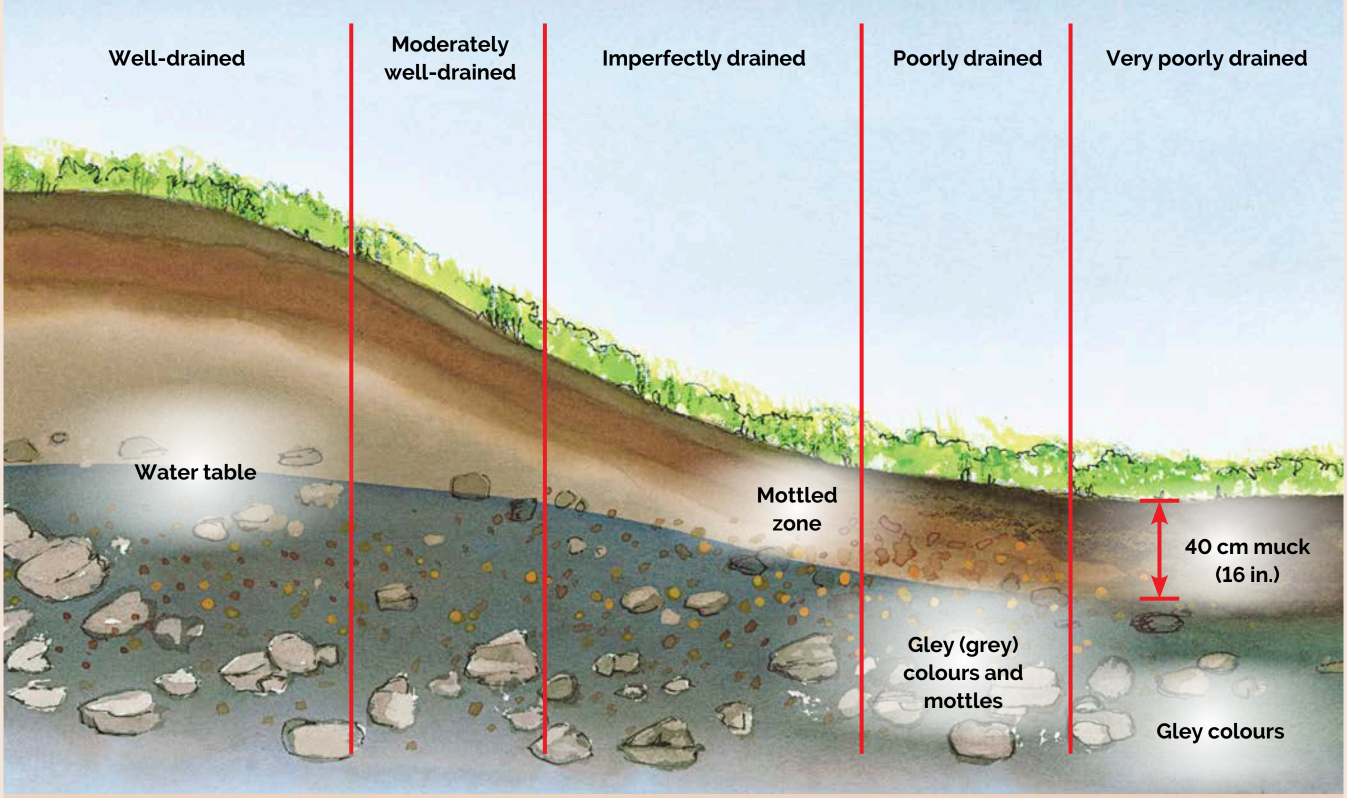
WATER TABLE

The upper surface of groundwater is called the water table. The water table's depth fluctuates over the year according to levels of precipitation, evapotranspiration and deep percolation. Water table levels are also affected by water usage, especially in highly irrigated areas during dry years.

In late fall, precipitation generally exceeds evapotranspiration rates, causing the water table to rise. The water table will reach its highest elevation and peaks in early spring following snowmelt and accumulated rainfall.

The water table drops throughout the growing season as crops mature and soils receive less precipitation (normally) in July and August. Evapotranspiration rates are the highest during the summer months. In most cases, the water table is at its lowest (deepest) levels in early September.

In droughty soils (with a drainage class of rapid or very rapidly drained), water table activity is not observed in the top 1 m (3 ft) of the soil. On some landscapes, the depth to water table may exceed 10 m (30 ft).



By observing soil colours, you can get a good idea of the seasonal fluctuations of soil water tables. Dull, grey (gley) colours indicate zones or depths of permanent saturation, whereas layers in the soil with rust spots (mottles) indicate a fluctuating water table. Soil water tables normally mimic local topography but tend to be deeper on hills and knolls and closer to the surface in depressional areas.

SOIL DEGRADATION AND DROUGHTY SOILS

Erosion can contribute to moisture stress. If an area has been severely eroded by poor management or extreme events over time, as is the case of channelized water erosion (e.g., rill or gully) or with tillage erosion, parent material may be exposed to the surface in localized areas. In most cases, the parent material has less favourable soil moisture characteristics than the lost subsoil and topsoil. Sometimes the exposure of a finer-textured or more compacted parent material can lead to reduced infiltration and more runoff, resulting in drought conditions.

In other cases, a more stony, gravelly or sandy parent material exposed at the surface will have higher infiltration rates, high permeability and a lower water-holding capacity. This also makes the soil droughty.

DROUGHTY SOILS AND CROP WATER REQUIREMENTS

Crops need water throughout the growing season. The key is to provide moisture before there is irreversible damage to the crop. For seeded crops, moisture early in the growing season is critical to ensure germination, emergence and early growth. For perennials, moisture may be more critical during flowering and fruit-filling.

Some soils are droughty throughout the growing season. In this case, the choices are:

- improve soil conditions
- irrigate
- choose drought-resistant crops, or
- retire the land to permanent cover with grass, shrub or tree species that can handle dry conditions.

Other soils are simply drier during the latter part of the growing season when evapotranspiration far exceeds moisture supply. In this situation, crop selection and strategic use of irrigation water together with water conservation BMPs (e.g., mulch, micro-irrigation, irrigation scheduling) work best in conjunction with BMPs that maximize water infiltration and soil water-holding capacity (e.g., no-till, cover crops, addition of organic amendments).

Mulch is often used to help cover the soil surface to conserve water and suppress weed growth. Typically, lighter-coloured materials (straw, woodchips or white plastic) are used because they reflect sunlight and reduce evaporative losses of soil water. Suppressing weed growth also reduces soil moisture competition.

CONDITIONS FOR DROUGHTINESS

Soil conditions

- coarse-textured soils (e.g., sands) and soils with high stone and gravel contents
- soils with shallow root zones, caused by perched water tables, shallow depth to bedrock or compacted subsurface layers
- hydrophobic soils — some organic soils become moisture-resistant and repel water
- surface soils (e.g., A horizons) with naturally low organic matter levels have low water-holding capacity
- eroded soils with exposed subsoil or parent materials
- soils with poor structure (i.e., low porosity and poor aggregation) that limit water infiltration and water-holding capacity

Topography and field conditions

- slope and slope position
  - soils in upper-slope positions are often farther from the water table than downslope positions
  - lack of capillary water in root zone
  - slope aspect (i.e., compass direction of downward slope) — south-facing slopes tend to be drier because of sun exposure
- runoff exceeds infiltration rates
- large bare fields prone to wind evaporation

Local climate

- regions with consistent annual moisture deficits (e.g., southwestern Ontario, south Renfrew County)

Past management

- intensive tillage leads to organic matter and soil structure breakdown
  - soil crusting — sealed soils have low infiltration rates, and heavy rains may lead to ponding and runoff and may not replenish soil moisture
  - subsurface compaction from equipment such as plow pans that restrict crop rooting development and access to moisture
- poorly timed tillage practices (e.g., too wet or too dry)
- physical weed control — more tillage equals more water loss in dry years
- poor weed control — competition for water from weeds
- overgrazing
- growing low residue crops (e.g., soybeans) or removing all crop residues

A management history of intensive tillage can lead to loss of soil organic matter and soil structure breakdown. This form of degradation will reduce the infiltration of precipitation and the moisture-holding capacity of the soil.

DIAGNOSTICS for Droughtiness

FIELD OBSERVATIONS

- more runoff and less infiltration
- wind and water erosion
- dry areas in field accompanied by light-coloured soils (e.g., ridge tops, knolls)
- soil crusting

CROP OBSERVATIONS

- uneven, spotty emergence
- stunted growth
- nutrient deficiencies
- yellow colouring — looks like N deficiency
- wilted plants with curled or cupped leaves, particularly in the afternoon or early evening
- shortened flowering period
- aborted flowers and seeds
- restricted root systems
- reduced yield, reduced quality
- high nitrate in forage crops (can be confirmed with a tissue test)
- herbicide carryover injury

Light colours on hilltops or across cultivated fields can be indicators of dry conditions, often associated with historical tillage erosion.

Frequent episodes of dust or soil blowing in moderate winds may indicate droughty conditions.

During dry weather, crops on droughty soils may suffer nearly irreversible damage. Twisted leaves on corn (left photo) are a mechanism for reducing water loss under drought conditions, and depending on the growth stage may affect yield. Tomatoes and peppers (right photo) will show signs of blossom end rot if soil moisture is limiting, which will affect yield and quality.

SOIL OBSERVATIONS

- dry, bare, powdery soils
- soil texture groups – coarser than loamy fine sands (e.g., medium and coarse sands)
- coarse fragments in soil (> 50% gravels and stones)
- soils that are shallow to bedrock
- soils prone to wind and water erosion
- 0–25% available water. To field test, ask yourself:
    - Is the soil dry?
    - Do aggregates break away easily?
    - Is there no staining on fingers?
    - Do the clods crumble with pressure?
- soil moisture at permanent wilting point

The feel test is a good indicator of soil moisture levels. Dry soils are powdery and will not form a cast (clump) when squeezed. At 100% moisture, a wet outline of water is left on the hand after squeezing.

Cropland or pasture soils that are shallow to bedrock and in upper-slope positions are prone to droughty conditions.

Suitable Best Management Practices (BMPs)

BMPs are classed as preventative or remedial. Often a combination of two or more BMPs (or suite of BMPs) is the most effective approach to resolve soil problems.

Choose the most suitable suite of BMPs from the following:

- conservation tillage — no-till, mulch tillage
- residue management
- crop rotation — include deep-rooted plants like forages
- cover crops — to improve soil structure, increase water infiltration and cover vulnerable soils
- organic amendments
- compaction mitigation — controlled traffic, limited axle loads, center tire inflation systems
- erosion control structures
- windbreaks
- vegetative wind strips
- water-conserving BMPs for irrigation (e.g., micro-irrigation, mulching, scheduling, monitoring)

Drip irrigation is used in many vegetable production systems. It improves crop yield, fruit quality and fruit size. It also uses water more efficiently and helps to overcome droughty soil conditions.

Adding organic amendments increases the soil carbon levels and improves soil structure and moisture-holding capacity.

For more information

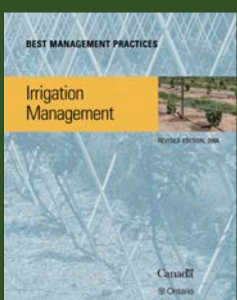
ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS

Many sources of supplementary information are available. Most can be found online at ontario.ca/omafra or ordered through ServiceOntario.

- *Agronomy Guide,* Publication 811
- *Soil Fertility Handbook,* Publication 611

Best Management Practices Series

- *Controlling Soil Erosion on the Farm*
- *No-Till: Making It Work*
- *Soil Management*
- *Irrigation Management*



Environmental Farm Plan (4th ed.) and EFP Infosheets

- Worksheet #15, *Soil Management*

Inquiries to the Ontario Ministry of Agriculture, Food and Rural Affairs

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Research and Writing: Ann Huber, Don King, Margaret Ribey, Soil Research Group (SRG)

Technical OMAFRA Coordinators: H.J.Smith (retired), Ted Taylor (retired) and Arlene Robertson

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