Best Management Practices

LOW FERTILITY

Soil fertility is considered low when the concentration of crop nutrients is insufficient to support sustainable crop production. Low or high soil pH can also indirectly cause low soil fertility, due to its impact on nutrient availability.

The natural fertility of the soil on-farm is determined by two key factors: the type of rock the soil was derived from and the conditions under which the soil was formed. As a result, different soils vary greatly in terms of fertility and related properties.

This infosheet describes a set of diagnostic tools used to describe the type, nature and extent of low fertility 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.

CANADIAN AGRICULTURAL PARTNERSHIP

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Low Fertility and Soil Health: The Basics

A soil may be low fertility for any of the following reasons:

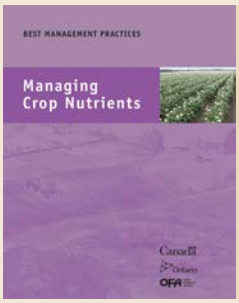
- It is inherently low in crop nutrients because of how it developed:
  - low clay or organic matter content, which reduces a soil's cation exchange capacity (CEC)
  - naturally high or low pH levels
  - granitic (low base) mineralogy
  - very high percolation rates, leading to leaching of nutrients
- It has been under poor fertility management:
  - no history of soil testing
  - cropped intensively with high nutrient-demanding crops without adequate nutrient application
  - fertilizer applied consistently below recommended rates
  - no application of organic amendments
- It has been degraded because of poor soil management:
  - erosion of topsoil and possible exposure of parent material at or near the surface
  - extreme high or low pH levels from exposed parent materials
  - low organic matter due to poor crop rotation (e.g., continuous soybeans)

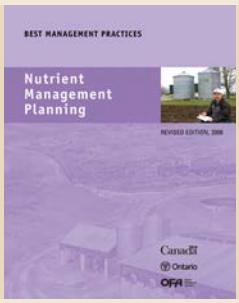
Without adequate nutrient replacement, fields that are cropped with whole-plant, high nutrient-demanding crops (e.g., such as corn silage) are susceptible to becoming low in fertility over time.

A lack of available nutrients causes delayed or stunted plants that fail to yield and can become more susceptible to pests and diseases.

Chronic low fertility reduces crop biomass and the conversion of crop residues into soil organic matter.

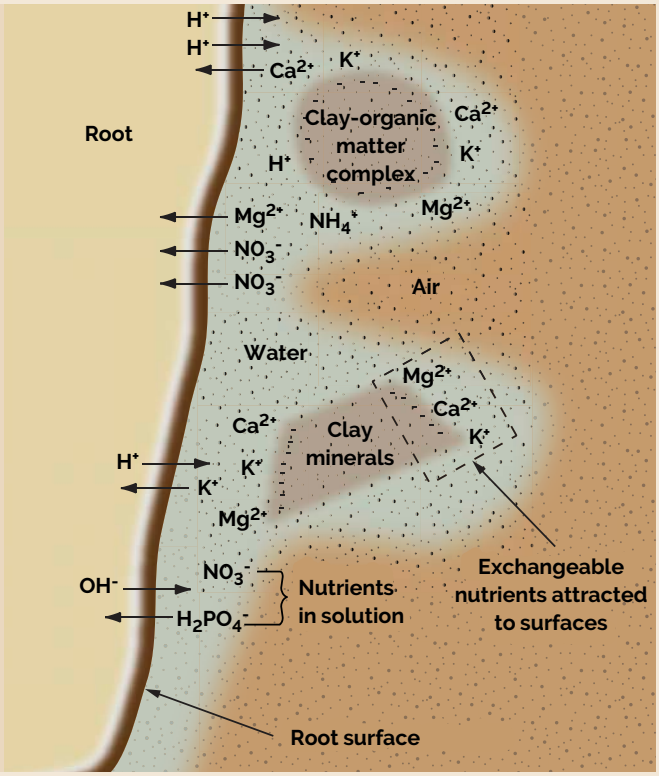
SOILS AND NUTRIENTS





For detailed information on soils and nutrients, see the OMAFRA BMP books, *Managing Crop Nutrients* and *Nutrient Management Planning*.

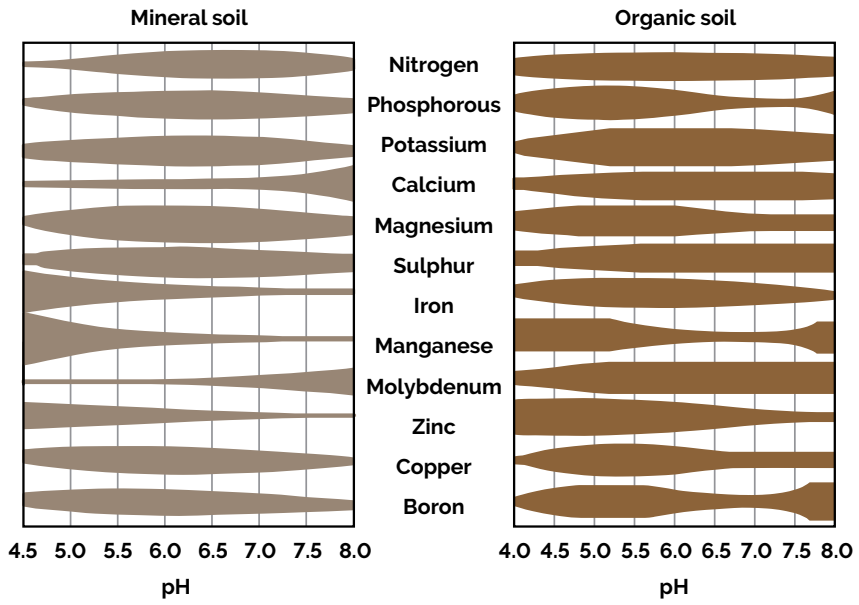
Clay and organic matter particles, which are referred to as soil colloids, are negatively charged. They hold onto and exchange positively charged nutrients (cations, e.g., Mg^{2+}, K^{+}, Ca^{2+}) with the soil solution. Clay and organic matter content determine the cation exchange capacity (CEC) of a soil. When the soil solution becomes low in a particular nutrient, it is released from the soil colloids into solution making it available for plant uptake. As roots take up cations, the charge is balanced through release of a cation (e.g., H^{+}) or by the uptake of an equivalent charge from an anion, such as nitrate (NO_3^{-}). Soils with low CECs may be inherently low in fertility.



NATURAL SOIL PROCESSES AND PLANT NUTRIENTS

Originally, most of the nutrients in soil (except nitrogen) were part of the chemical structure of rocks and minerals making up the geological deposits (parent materials) upon which modern-day soils were formed. Over many thousands of years, various natural forces, together known as weathering, broke down the rock and its minerals. This breakdown released some of their nutrient content in forms that plants can use. Slowly, weathering continues to release small amounts of nutrients from these sources.

Many of the chemical reactions that occur in soils remove nutrients from the soil solution. Some of these reactions produce compounds that are insoluble in water and thus unavailable to plants. Nutrients in these compounds remain unavailable until other reactions break the components down. Soil pH has a major influence on which chemical reactions occur and which compounds are produced. pH also affects the solubility of the compounds. Therefore, the availability of most nutrients will change if the soil pH is altered.



Plant nutrients can be present in the soil but not necessarily in a form that is available for plant uptake. Soil pH greatly influences whether a nutrient is available for plant use.

ROLE OF SUBSOIL AND SOIL PARENT MATERIALS IN SOIL FERTILITY

Subsoil is much lower in fertility and contributes a much smaller proportion of the nutrients taken up by plants than topsoil. Several factors contribute to this:

- Most of the plant root system is in the topsoil.
- Nutrients have not been added to the subsoil.
- There is less organic matter in subsoil.
- Fewer nutrients have been released in subsoil because subsoil is less subject to weathering compared to topsoil.

Ontario's soils have developed from various types of parent material. Soil parent material can range in pH from acidic to basic, depending on its origin, mineralogy and chemistry. Soil parent materials derived from calcitic and dolomitic limestone bedrock are usually calcareous and alkaline. They contain large quantities of calcium (Ca), magnesium (Mg), potassium (K) and iron (Fe). The availability of several nutrients is reduced in soils formed from such parent materials due to their alkalinity.

Soil parent materials located on or near the Canadian Shield, however, are often acidic and reflect the mineralogy of the Shield bedrock (e.g., granites, gneisses, etc.). These may be high in potassium, iron and molybdenum, but low in magnesium and calcium.

Bedrock composition influences soil pH, which in turn affects inherent soil fertility.

ROLE OF SOIL ORGANIC MATTER IN SOIL FERTILITY

Soil organic matter contributes to soil fertility in the following ways:

- Soils high in organic matter have a higher CEC.
- Organic matter itself stores nutrients and releases them as it decomposes.
- Organic matter contributes to soil structure and aggregate stability, which creates a good rooting environment for crops to access nutrients.

Degraded soils with low organic matter levels are less fertile than healthy soils with adequate levels of soil organic matter.

IMPACT OF SOIL TEXTURE AND DRAINAGE ON SOIL FERTILITY

Coarse-textured soils, where the water table is not present in the top metre of the soil (e.g., rapidly drained soils), have high percolation and leaching rates for mobile nutrients (e.g., nitrate-nitrogen). These soils often have low CEC, meaning there are few exchange sites present to hold nutrients.

Poorly drained soils can be anoxic (i.e., without oxygen). Nitrate-nitrogen will denitrify (i.e., convert to nitrogen or nitrous oxide gas and be lost to the atmosphere) in wet, anaerobic conditions, leading to a loss from the system. Subsurface drainage and improved timing of nitrogen application help to minimize risk of denitrification.

EFFECTS OF SOIL AND CROP MANAGEMENT ON SOIL FERTILITY

Cropping system

- A diverse crop rotation that includes legumes (e.g., clover, alfalfa) provides soil fertility benefits. Crops that remove large quantities of nutrients will deplete soils over time unless fertilized to meet crop requirements. The same crop will remove the same proportions and types of nutrients year after year.

4R nutrient stewardship

- Right source — using an appropriate nutrient source that maximizes plant uptake will increase biomass return
- Right rate — applying nutrients based on soil test results reduces the risk of over or under-application
- Right time — applying nutrients close to the period of maximum uptake optimizes crop nutrient use efficiency
- Right place — placing nutrients as close as possible to plant roots increases crop uptake and minimizes losses

Fertilizer application through strip-tillage is one example of applying the 4R principles of nutrient stewardship. In this case, fertilizer is being sub-surface applied in spring shortly before seeding the crop.

Organic amendments

- A soil that receives organic amendments from manure, compost or cover crops will be more likely to maintain or increase in organic matter, which enhances its ability to hold onto and exchange nutrients.

EFFECTS OF SOIL DEGRADATION ON FERTILITY

Degraded soil showing signs of low fertility may have one or more of the symptoms shown in the following photos:

EROSION — Tillage and water erosion can expose parent material at or near the surface. Parent materials are naturally less fertile than well-managed topsoils. Soil parent materials can display pH extremes and lower nutrient levels, as well as lower water-holding capacity, increased bulk density, lower organic matter levels and higher coarse fragment contents.

SURFACE CRUSTING — Poor surface soil structure is most often linked with low soil organic matter levels either naturally or from poor management. Low levels of organic matter contain fewer organic sources of nutrients (e.g., N+P) and fewer exchange sites to hold other nutrients for crop uptake.

COLD AND WET CONDITIONS — Soils that have become cold and wet from poor soil structure and/or subsurface compaction will be at greater risk of losing nitrate-nitrogen to denitrification.

CONDITIONS WHERE LOW FERTILITY IS LIKELY

Soil properties

- Exposed soil parent material — will lower organic matter levels and alter pH, which decreases overall fertility.
- Low clay content — silty and sandy soils have fewer cation exchange sites (lower nutrient-holding capacity) and become acidic more quickly.
- Saturated soils — nitrates are subject to denitrification loss.
- Low organic matter — results in lower CEC, fewer stored nutrients and a reduced capacity to buffer pH changes.

Soil life

- Low populations and diversity of soil life (e.g., earthworms, bacteria and fungi) may result in decreased nutrient turnover from crop residues and reduced overall nutrient availability.

Growing high nutrient-requiring crops without a soil fertility program in place can lead to soil fertility problems.

Coarse-textured soils can be prone to leaching. Nitrogen management remains a challenge on rapidly drained sandy soils.

Past management

- Lack of a prior soil testing and fertility management program
- Degraded soils with exposed subsoil or parent material
- History of high nutrient-requiring crops without adequate replenishment
- Excessive tillage, which accelerates the breakdown of organic matter and loss of exchange sites for nutrient retention
- Intense grazing with no pasture improvement or management

Degraded soils, such as eroded knolls with parent materials exposed on the soil surface, have fewer exchange sites and lower nutrient availability, leading to stressed crops.

Diagnostics for Low Fertility

FIELD OBSERVATIONS

- Uneven stand development — more so on hilltops
- Stressed or stunted crops — poor growth on knolls, depressional areas and headlands
- Disease — nutrient-deficient crops are more susceptible to pest pressures
- Weeds — low fertility and poor crop canopy may provide an ideal growth environment for weeds

CROP OBSERVATIONS

- Reduced root growth — less water and nutrient uptake
- Visual nutrient deficiency symptoms
  - Nitrogen (N) deficiency appears as V-shaped chlorosis on lower leaves in corn
  - Phosphorous (P) deficiency can appear as purpling of lower leaves along tips and leaf margins
- Lodging in annual field crops can be indicative of low potassium availability
- Decreased yield
- Poor fruit or vegetable quality

SOIL OBSERVATIONS

Low fertility is not actually a visible characteristic of soil. However, areas where low fertility is expressed in the crop may be due to other factors that are often visible:

- Light-coloured topsoil means lower organic matter, less nutrient retention and reduced nutrient availability.
- A lack of earthworms indicates poor soil conditions and reduced nutrient cycling.

It is not uncommon to observe uneven development over a field due to areas with low fertility.

V-shaped yellowing on lower leaves, followed by death of tissues, is characteristic of nitrogen deficiency in corn.

Cereals will lodge when potassium (K) is not sufficiently available for crop growth.

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 BMPs for your circumstances and goals.

- Conduct soil testing regularly and follow Ontario nutrient guidelines.
- Use 4R nutrient stewardship principles.
- Diversify crop rotations to include legumes, small grains and perennials where possible.
- Use conservation tillage (e.g., no-till, mulch till) to protect soil from degradation.
- Use cover crops to scavenge nitrogen, reduce leaching, cycle nutrients and build organic matter.
- Use deep-rooted crops to cycle nutrients from deeper in the soil profile to the soil surface.

The most reliable indicator of soil fertility is a soil test.

Growing nitrogen-fixing legumes as forage crops or cover crops will improve soil fertility, add organic matter and improve seedbed structure.

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.

- OMAFRA Factsheet 12-053, *Soil Erosion – Causes and Effects*
- Publication 611, *Soil Fertility Handbook*
- Publication 811, *Agronomy Guide for Field Crops*

Best Management Practices Series

- *Controlling Soil Erosion on the Farm*
- *Field Crop Production*
- *Soil Management*

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

- Worksheet #15, *Soil Management*

Ontario Crop IPM Soil Diagnostics
omafra.gov.on.ca/IPM/english/soil-diagnostics/index.html

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