Chemical Soil Health Indicators

Chemical soil health indicators are correlated with the capacity of the soil to provide nutrients for plants and retain chemical elements or compounds harmful to the environment and plant growth. The availability and quantity of macro and micronutrients (Figure 1) in agricultural soils can significantly influence the occurrence of deficiencies or toxicities, which, in turn, impact crop productivity. Macronutrients (Table 1) are elements that plants require in relatively large amounts, while micronutrients are needed in much smaller quantities.

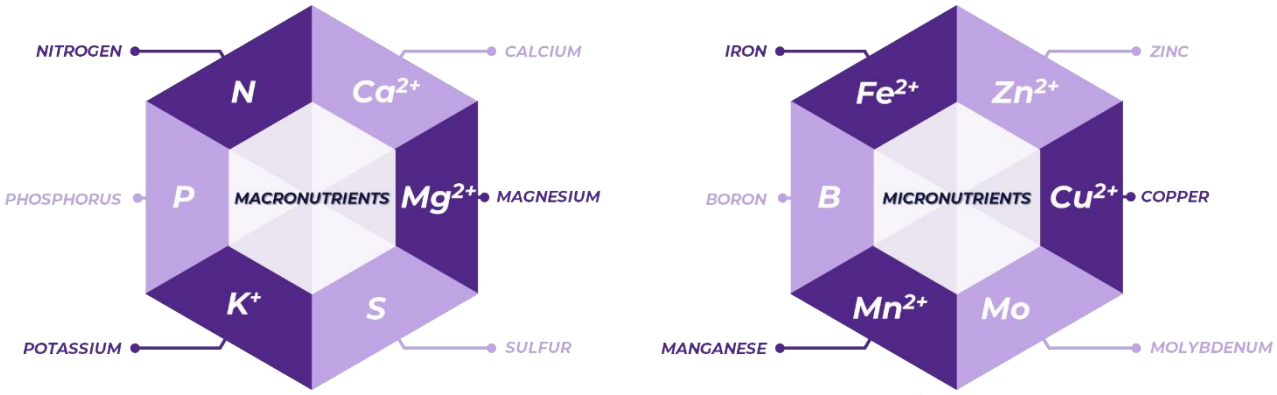

Figure 1. Macro and micronutrients. Chlorine (Cl) and nickel (Ni^{2+}) can also be considered micronutrients.

Besides nutrients, other often-measured chemical indicators include soil pH, cation exchange capacity (CEC), active carbon, and soil electrical conductivity.

SOIL pH

Soil pH refers to soil acidity or alkalinity, defined by the hydrogen ions in the soil solution, with a scale from 0 to 14 and 7 being neutral. Above 7 is alkaline, and below 7 is acidic. pH changes can significantly impact soil chemistry and biology. For most crops, a pH between 6 and 7 is considered ideal since this is the range where most nutrients will be available for uptake. However, a few plants prefer acid or alkaline soils.

CEC

It indicates the soil's ability to retain and exchange positively charged ions (cations), such as Ca^{2+}, Mg^{2+}, and K^{+}. Soils with a higher CEC can hold more nutrients and promote better plant growth. These soils are particularly beneficial as they do not lose nutrients easily, ensuring a steady supply of essential nutrients to crops throughout the growing season.

ACTIVE CARBON

Active carbon, also known as permanganate oxidizable carbon (PoxC), is a fraction of the soil organic matter that is oxidizable in the presence of potassium permanganate. This type of carbon is usually more readily available to decomposition by microorganisms. This fraction includes fresh organic material, soil microbial biomass, particulate organic matter, and compounds such as carbohydrates and proteins. Active

carbon serves as an indicator of how cropping and soil management practices affect soil organic matter content.

ELECTRICAL CONDUCTIVITY (EC)

Soil EC measures the ability of the soil to conduct electrical current, primarily through water-filled pores where ions from salts dissolved in soil water carry charges. The concentration of cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_4^{+}) and anions (SO_4^{-}, Cl, NO_3^{-}) determines EC. In agriculture and natural resource management, EC is mainly used to assess soil salinity but can also estimate other properties like soil moisture and nutrient content. High EC values (>4 dS/m) indicate saline soils, limiting growth for salt-sensitive crops. EC mapping through sensors has been widely used in precision agriculture to estimate nitrate concentration, showing a correlation where nitrate increases with higher EC values.

Table 1. Role of macronutrients on plants.

ROLE OF MACRONUTRIENTS ON PLANTS	
N	Key element for protein synthesis, chlorophyll production, and plant vigor.
P	Helps with energy transformation, cell division and growth, and root development.
K^{+}	Controls the movement of water, nutrients, and carbohydrates in plant tissue.
S	Plays a key role in chlorophyll production and photosynthesis.
Mg^{2+}	Central core of the chlorophyll molecule in plant tissue.
Ca^{2+}	Helps plants build strong cell walls to provide a rigid structure and protection.

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