



# The Mineral-Microbe Theory of Tree Decline

By Normand Helie February 11, 2024

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Under each step we take there is a dynamic world of living microorganisms. In a single ounce of dry soil, millions and sometimes billions, of diverse microbial species exist. In the earliest geological history of our earth, the beginnings of this incredible world of microbiology can be found. These microorganisms, also called microbes, colonize the surface of newly deposited minerals almost immediately. In nature, microbes are the first living organisms on minerals. The diversity and the complexity of microbes can be simplified by categorizing microbes into two groups: mineral-microbes or plant-microbes. The mineral-microbe interacts closely with earth's elements and transfers energy and nutrition to the plant-microbes which then assist plants by making nutrients more available for absorption.

But when minerals decrease from soil through weathering, leaching, cropping, or interference in nutrient recycling (e.g. removal of leaf litter), the mineral-microbes go into survival mode. These specialized microbes shut down and wait for the next natural deposit of minerals, such as lava from a volcanic eruption.



*Within our soils, billions of microorganisms assist in providing nutrients to growing plants.*

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As minerals are depleted from the topsoil the mineral-microbe population shifts to micro-organisms that are semi-toxic to plant-microbes. As a result, essential plant-microbes can no longer survive and thrive in top soil. Plant-microbes need energy from mineral-microbes. When this microbial web is broken, the soil becomes unhealthy, commonly called sick soil, and contributes to slow plant establishment and tree decline.

All soils require fresh residues of life supporting minerals to keep them healthy and thriving. But delivering a fresh supply of minerals should not be misconstrued as the addition of fertilizer or organic matter. Both of these materials can have deleterious effects on soil health and our environment respectively. Many may be surprised to learn that soil weathering and development are the same. It is a perfect paradox and can be difficult to understand because as soil organic matter increases, soil weathering of minerals also increases.

### **Measuring Total Mineral Nutrition to Ensure Soil Health and Resiliency**

Contemporary soil testing will not detect total mineral deficiencies in the soil. Chemical analysis is done by the extraction of nutrients from soil. These extractions give accurate estimates of available nutrients during the next three growing seasons at best. This type of soil test is very important because it can help researchers develop the most nutritious plants to aid in world hunger. But, the actual mineral total of the soil is not measured in these tests. Total minerals are calculated values from the extraction sum totals. Agricultural testing is based on annual yields. The earliest soil genesis is ignored. Agricultural science says soil

formation begins when plants grow but they do not acknowledge that microbe development from minerals occurred over millions of years before plants developed. The mineral-microbe interactions are not accounted for in their soil formation system.



*Particle density testing of soil.*

Agricultural soil scientists are only interested in the here and now conditions of the soil. A causal relationship between tree decline and current soil testing are improbable. Current soil testing doesn't measure the loss of mineral content in a weathering (developing) soil.

Agricultural soil tests fall short in the bigger picture for urban and forest soil health. Total mineral nutrition must be measured to ensure natural soil health and its juvenile resiliency.

### **Our Soils are Becoming Less Productive Agriculturally**

The total mineral content can be measured by relative specific gravity test. A density test determines the mass (weight) of a given volume of a solid without any air pockets. Soil scientists call it particle density. The narrow range for most soils with 3 to 5% organic matter is 2.60 and 2.75 g/cc. The majority of soils are made up of quartz, feldspar, and silicates and fall within these density ranges. Sometimes unusual amounts of mineral with high particle density such as magnetite, garnet, epidote, zircon, tourmaline, and hornblende increase the particle density above 2.75 g/cc (Brady, 1984). Today, values higher than 2.75 g/cc are very uncommon because of advanced weathering of soil and this is an indication that our soil is becoming less productive agriculturally.



*Early 19<sup>th</sup> century drawing of cows grazing near the Great Elm on Boston Common.*

The Boston Common humbly began as an agricultural soil and was highly productive for growing trees in its earliest years. As it transitioned to an urban landscape, with densely planted elm trees, the soil conditions became weathered and depleted of minerals.

### **A Philosophical Interlude of Soil Weathering and Tree Decline**

Geologically speaking, the Appalachian Mountains are a very young mountain range. One thousand years ago, the soil particle densities were much higher. Soil weathering has removed smaller dense soil particles and only larger fragments can now be found. This is why rock hounds hunt for valuable semi-precious gems in these mountains. Large aggregate can be found but it does not support microbes in the soil. These once dense soil minerals were instrumental in the successional development of soil and the forest canopy.



American Chestnut photo credit: Peatcher at German Wikipedia., CC BY-SA 3.0

*Leaves and seed of American Chestnut Castanea dentata.*

Species like American chestnut trees originated in this once mineral rich environment. The American chestnut tree thrived *exclusively* in this niche mountainous terrain. However, after thousands of years of soil erosion and weathering the tree became vulnerable to parasitic cankers. The death of the American chestnut tree demonstrates the significance of the mineral-microbe connection. Only tree roots remain because minerals and their microbes can't support the whole tree. The American chestnut tree declined due to soil weathering and forest succession. It died rapidly from a canker disease called chestnut blight. As soils weather, the forest canopy changes and we call it tree decline.

### **Soil Development is a Paradox**

Organic matter also has particle density but is much lower than mineral density. The normal range for organic matter is closer to water and much wider than the mineral range at 0.5 and 1.5 g/cc. Organic matter can also absorb and increase its mass by accumulating minerals in its diverse amorphous structure. This could interfere with the plants ability to access important nutrients such as phosphorus and calcium. Remember, soil weathering is the same as soil development. As soils weather, organic matter increases. We always think of the benefits of organic matter but organic matter contributes to soil weathering. Organic matter holds water and nutrition in the top soil but it contributes to the depletion of minerals in soil. The water and its chemistry from organic matter accelerate mineral loss. At the same time, soils rich in minerals develop and increase soil organic matter. Soil development is a paradox.

## Mineral Diversity Increases Microbe Diversity

It is not uncommon to find soils in urban and agricultural settings to have particle densities of 1.7 to 2.4 g/cc (personal experience). This is significantly lower than the average 2.65 g/cc. This indicates our soils lack important minerals such as feldspar which is beneficial for mineral-microbes. Mineral microbes support plant-microbes by direct transfer of energy and nutrition.

### ***The whole is greater than the sum of its parts-Aristotle\****

Soil health tests should begin with how soils form and their total mass. Both soil formation and their developing process are important in understanding each soil. This will make us better stewards of our resources. All matter has energy. The more dense matter is; the more energy it has. And this energy is transformed into our living landscape through a very complex and delicate biological web. This biological web is bigger than the plant-microbe world that we already know. The composition of mineral amendments should be regionally studied according to each soil family or series. Soils with higher density (2.65 g/cc) will be healthier than lighter soils (less than 2.5g/cc). Using density tests relative to specific gravity will quantify the weathered condition of soils and can be especially helpful for sandy topsoil. Mineral diversity increases microbe diversity. **A soil mineral density test is a valuable tool in determining the relationship between available mineral diversity and declining tree health.**

\*Aristotle is one of the first soil ecologists and makes this famous quote from his observations on nature.

### **Literature Cited**

Aristotle. Metaphysics. Book 1, Chapter 1, 980a22

Brady, N. C., 1984. *The Nature and Property of Soils* 9<sup>th</sup> ed. Macmillan Publishing Company

### **Helpful Links**

[Apple replant disease research](#)

[Soil minerals affect taxon-specific bacterial growth](#)

[A critical review of mineral-microbe interaction and co-evolution: mechanisms and applications](#)