Building Soil

Regenpreneur

Regenerative Changemakers

Understanding Soil

Soil is created through life processes working upon minuet sediments, mixing those sediments with organic matter and sticking them together with biological slimes to create soil aggregates that improve air and water circulation and allow nutrients to be stored. If the soil habitat is sheltered by plants, and receives a regular source of organic matter to be broken down by decomposers, it provides a habitat in which life can flourish. The healthy soil ecosystem has a diverse range of life from decomposers that break down organic matter and supply these nutrients to the soil in their faeces, bacteria that have a diverse range of roles recycling soil nutrients and fungi that create a complex network in the soil. It is our role as regenerative farming engineers to create diverse and abundant habitats which will provide the full range of resources to support fulfilling lives while nurturing our habitat and soil for future generations.

Soil is essential for life on land. Soil is composed of minerals (sand, clay and silt), air, organic matter. An ideal agricultural loam soil has approximately 45% minerals, 25% water, 25% air and 5% organic matter. Soil minerals build up due to the erosion of rocks and form a substrate into which plant roots can anchor themselves and which also provides a home for soil life.

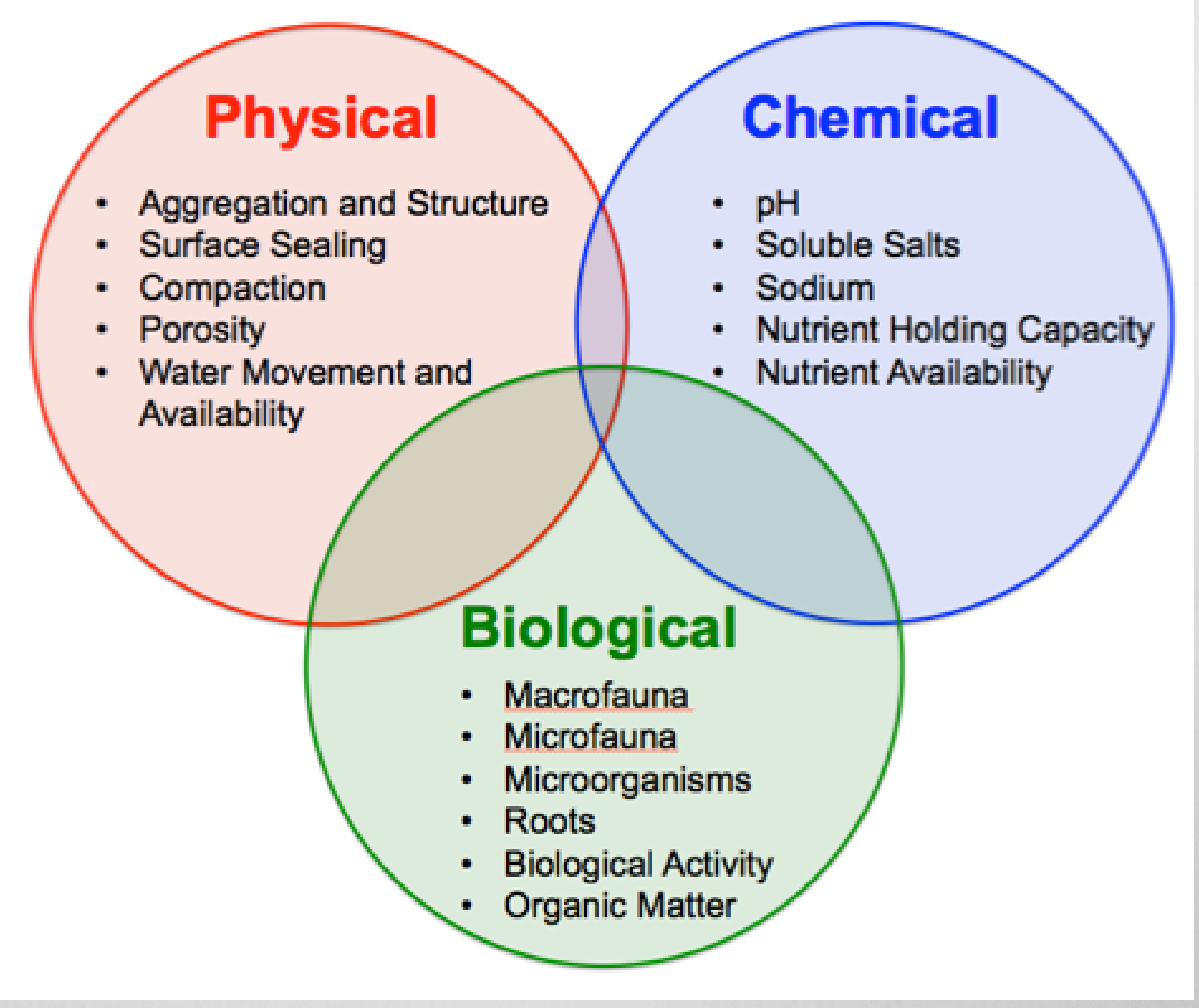
The necessary treatment for soils varies by the conditions, but the general goal is to have good structure and permeability, which is more or less achieved with high organic content. Organic content also helps to balance the pH levels in soils and helps regulate water and salinity. Thus, we have to concentrate on maintaining our topsoil and designing agricultural systems that will provide a continuous source of organic matter to build soils and maintain their fertility.

Within permaculture farms we aim to create systems that improve the quality and quantity of soil over time. This may result in less short term yield when compared to conventional agriculture systems (due to the requirement to feed the soil adequately and not over-strip it of resources), but in the long term the production of crops is far higher due to the sustainable nature of production that can be sustained indefinitely.

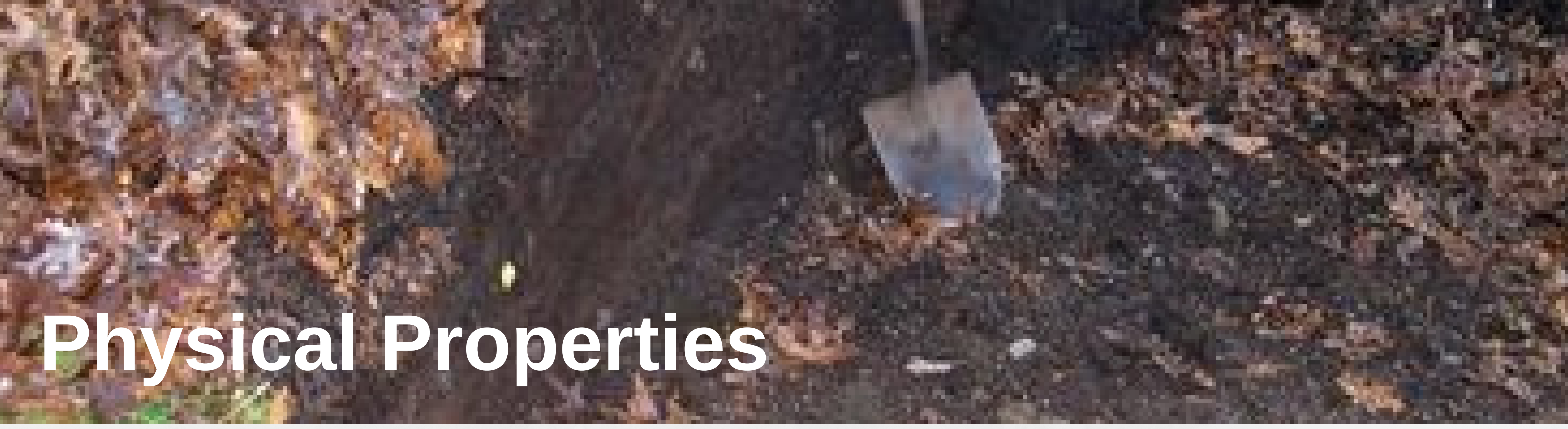
Understanding Soil

Water and air are important components of soil for plants and other organisms that live in the soil. Water in the soil is absorbed by plant roots and creates a humid environment which is important for many soil organisms to survive in. Soil organisms and plant roots also require oxygen from the air in soil to respire and create energy for cellular processes.

Organic matter in the soil (or hummus) builds up from the decomposition of dead plants and animals. Before being decomposed, this provides a food source to support a diverse ecosystem of life within the soil. When organic matter is decomposed it helps absorb water, create extra air space and balance atmospheric carbon. A growing appreciation is emerging that building soil carbon (by increasing organic matter in soil) may be the best solution to combat rising atmospheric carbon associated with global warming. With the added benefit of improving soil properties to support agricultural production.



To understand soil better we can break our understanding into physical, chemical and biological properties.

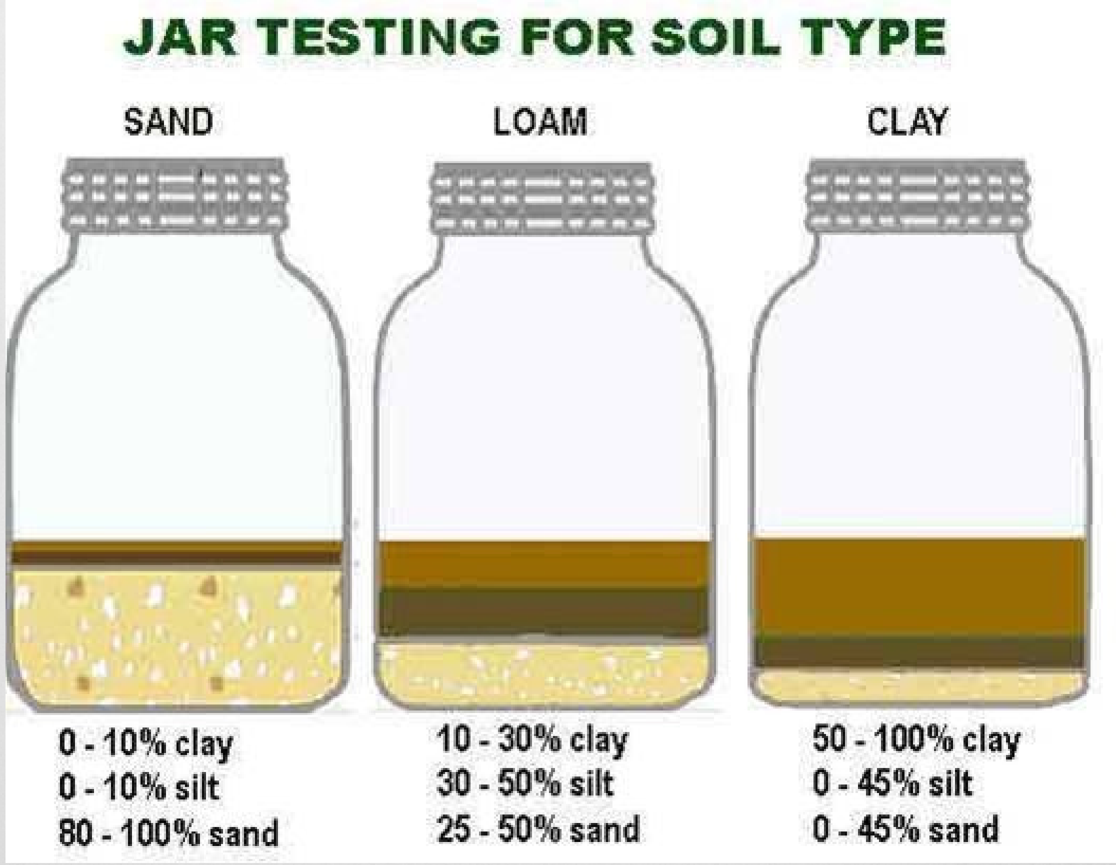


Physical Properties

The physical properties of soil describe the composition of particles within a soil. At a simple level we can describe the composition of sand, silt and clay based on the texture of a soil when rubbed between the fingers or when separated into different layers when mixed with water. These mineral particles have a dramatic impact on the properties of soil.

A soil with a high proportion of sand allows water to drain through it and has good air circulation, but will also dry out quickly. While a soil high in clay has small mineral particles tightly packed together, resulting in poor water drainage and making it hard for air to circulate within it. A loam soil has a fairly even proportion of clay, silt and sand and allows good air circulation while also retaining water. Loam soil make the best agricultural soil type. The soil pyramid is used to classify a soil depending upon the proportion of sand, silt and clay it contains.
At a more advanced level we can also describe its structure, density, porosity, consistency, and colour of soil. Soil structure refers to the way in which soil particles are grouped or bound together to form lumps or aggregates. There are two main types of soil structure, single grained and compound structure. The structure of soil can be changed, modified and improved or damaged depending on the various soil management practices adopted like tillage, manuring, liming, rotation of crops, irrigation, drainage etc.

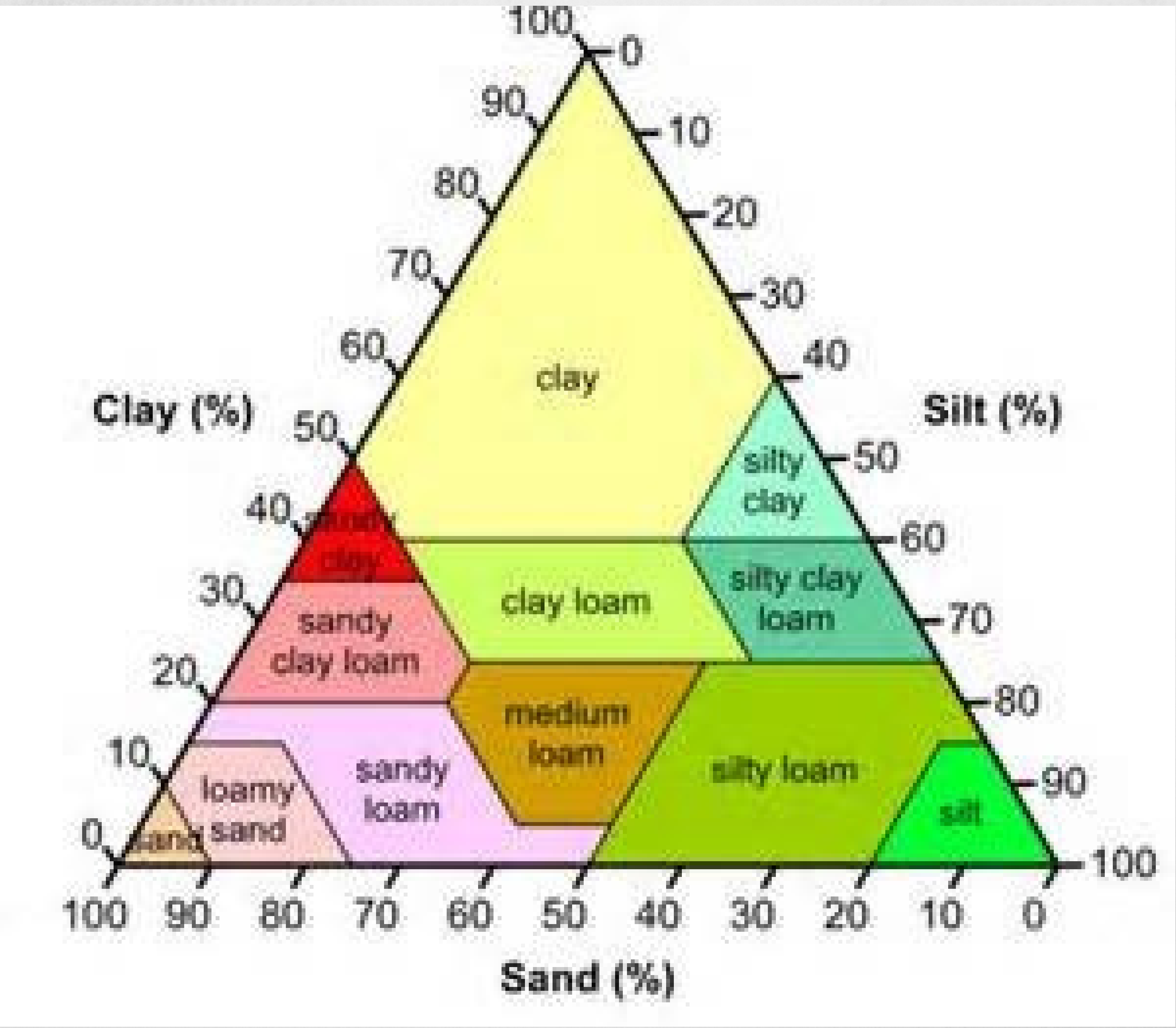
In between the particles there are empty spaces which are occupied by air and water and are termed as pore spaces. There is a higher percentage of pore spaces in sandy soils and these soils are free draining and never remain water logged.



A float test to determine mineral composition of soils

Physical Properties

Soil consistency is a combination of properties that determine the resistance of the dry soil to crushing or pulverising action by implements and when wet its ability to be moulded or changed in shape. All soils have cohesive and adhesive properties. Sandy soils have these properties to a much lesser degree than fine texture clay soils. Soils also have various shades of black, yellow, red and gray colours useful in soil classification. Soil colour is indirectly helpful in indicating many other properties of soils e.g. a dark brown or black coloured soil indicates its high organic matter content and fertility. A red or yellowish soil shows good aeration and proper drainage. A white or black colour due to accumulation of certain salts of alkali indicates deterioration of soil fertility and its unsuitability for normal growth of many crops.



A soil pyramid used to soil type based on composition of minerals (sand, silt and clay).

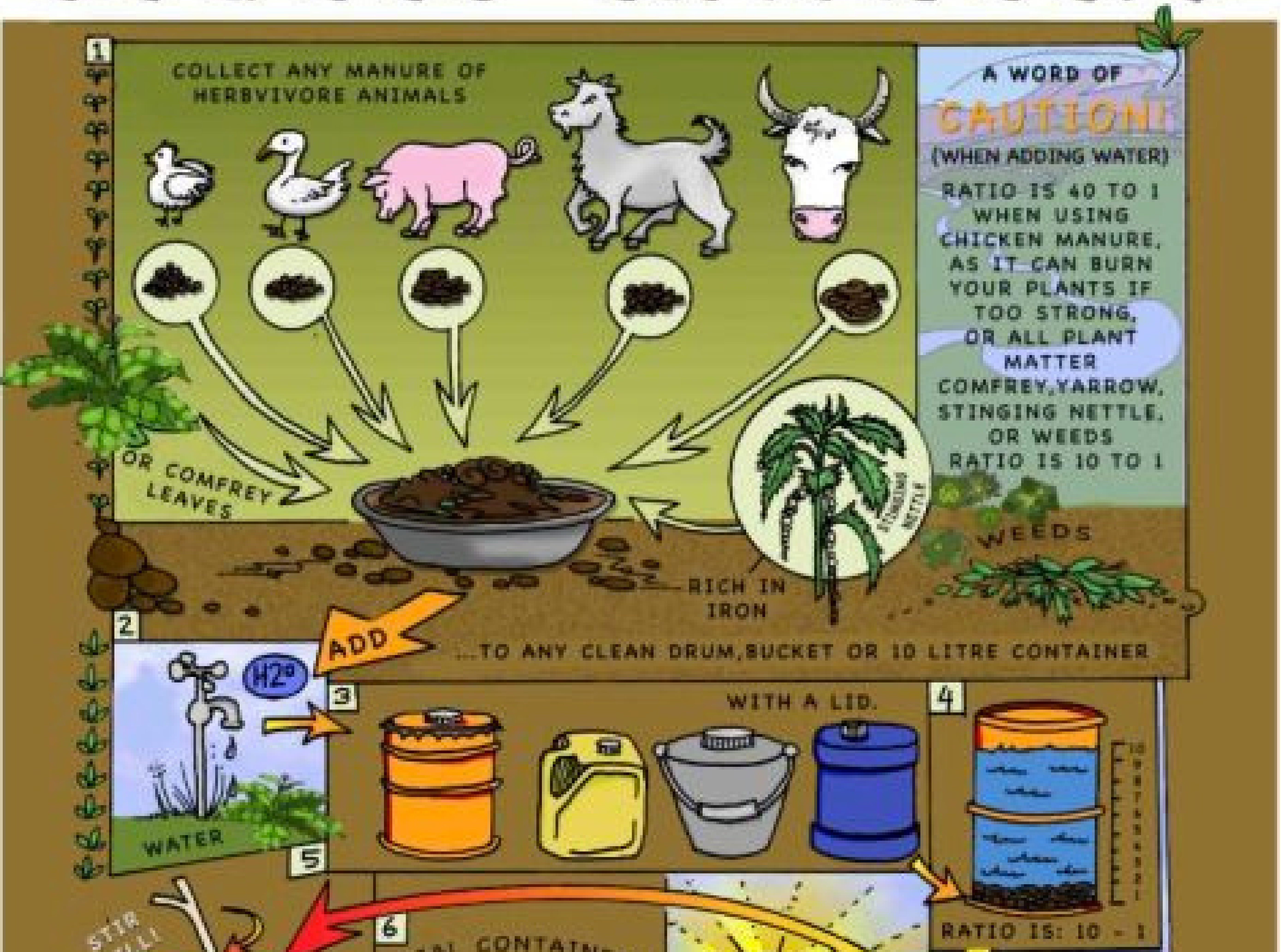
Chemical Properties

The chemical properties of a soil describe the composition of mineral elements, nutrients, and pH within a soil. A soil test can be performed at a site to obtain a list of those minerals and nutrients a soil contains that are important for plant health and growth. Many of the minerals in a soil originate from the parent rock material and are recycled by the decomposition of plant and animals in the soil.

The three primary nutrients in soil are NPK: nitrogen, phosphorus, and potassium. Despite the rampant use of chemical fertilizer, these can all be sourced naturally. Nitrogen can come from certain trees and plants, especially legumes, that have bacterial colonies on their roots that fix nitrogen into the soil. When the plants die or are pruned, the roots drop and release nitrogen beneath the soil for other plants, as well as atop the soil with their leaves and branches. Phosphate, though deficient worldwide, is abundant in bird manure, including domestic birds, and there are also plants—palms and casuarina—that interact with fungi to fix phosphate into the soil. Lastly, potassium is readily available as it is present in all green material. Sea products, rock dust, manure, composting and vermiculture are all other natural ways of increasing mineral content and nutrients in the soil.

Soils hold onto nutritional elements in a way similar to the way they retain water: Positively charged nutrient molecules, cations, are attracted to the negative charges on the soil particles. The sites where cations attach to particles are cation-exchange sites Thus, clay retains more nutrients than coarser soils, just as it holds more water, because of the greater surface area (greater number of cation exchange sites) to which nutrients can adsorb. The ability to hold cation nutrients is called the cation-exchange capacity (CEC) and is an important characteristic of soils in that it relates to a soil’s ability to retain nutrients and prevent nutrient leaching.

LIQUID MANURE



Manures, compost, mineral accumulating plants, biochar all make good additives to creating composts that can be either applied directly or diluted into water to be applied as a compost tea.

Chemical Properties

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Salinity is another important chemical measure within soils. Some soils, particularly in arid regions, hold high levels of salt. Low rainfall prevents leaching of salts, so they build up in soils. Pan layers, common in arid regions, further inhibit drainage and leaching. Some fertilizers and amendments also can increase salinity.
Soil pH, parts hydrogen, is mostly determined by a soil's parent rocks. The scale centers on seven, which is neutral, becoming more acidic as the numbers get smaller and more alkaline as the numbers increase.

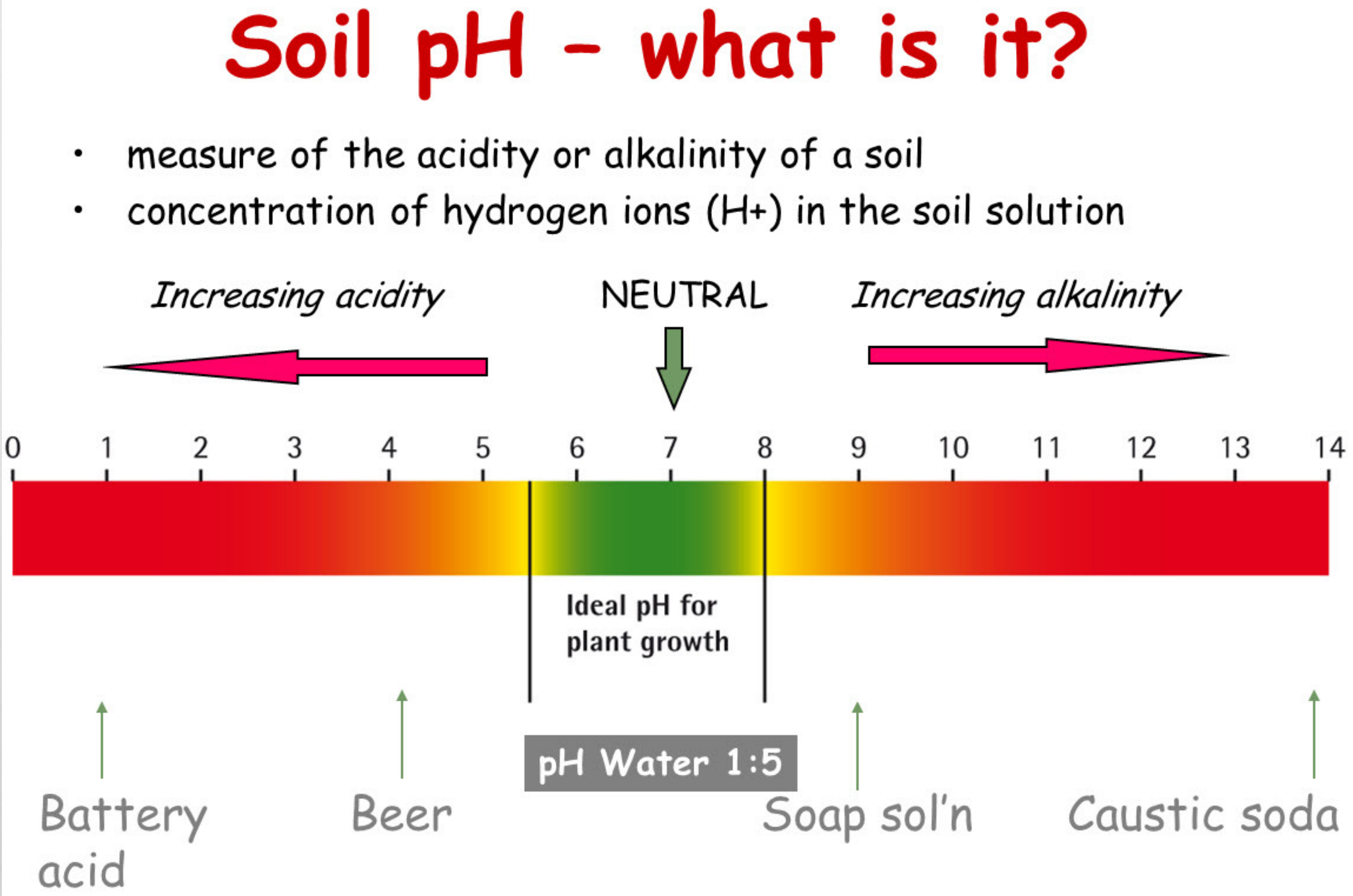
Each number in the scale exceeds the previous number by the power of ten, such that a six pH balance is ten times more acidic than a seven but five is 100 times more acidic. As the numbers move outside of four and ten, the possibilities of life become remote. These can be brought back towards neutral by adding sulfur to alkaline soils and lime or dolomite to acidic soils. Humid places are usually slightly acidic, while new volcanic, coastal, and arid places tend to veer towards alkaline. Gardens generally function best at a pH between six and seven, though pH levels are not constant, adjusting with thing like rain and time of day.

Chemical Properties

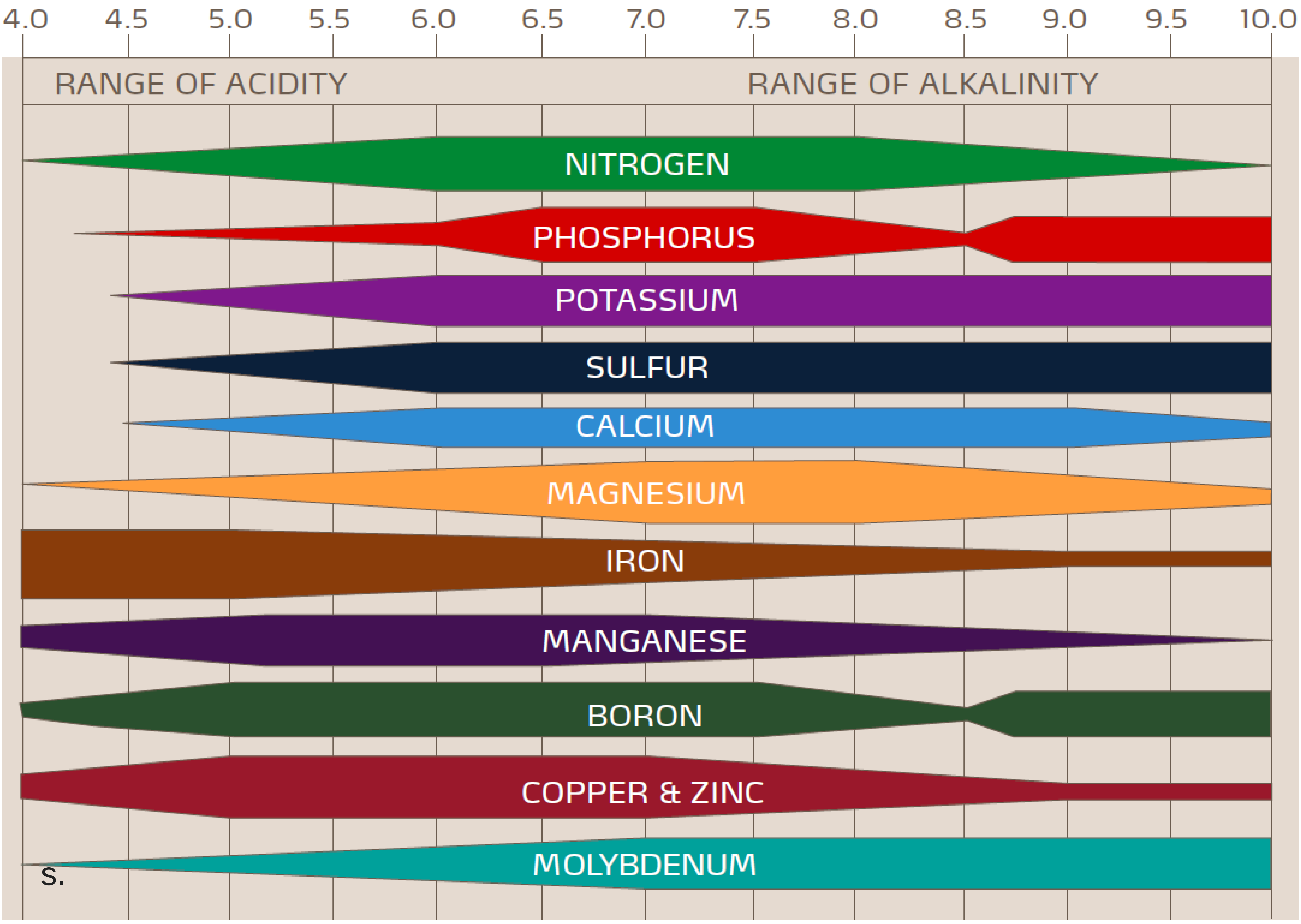
Soil pH is perhaps the single most important aspect of soil chemistry. Strictly speaking soil pH is a measure of the number of hydrogen ions (H+) present in a solution. In more common terms, it is a measure of alkalinity and acidity. The pH scale runs from 0 to 14. Seven is neutral, 0 is the most highly acidic value possible and 14 is the most alkaline, or basic, value. Most plants grow best in the range of 6.5 to 7.0, which is acidic, but only slightly. The so-called acid-loving plants prefer lower pH, in the range of 4.0 to 6.0. Under 4.0, few plants are able to survive. Slightly alkaline soil is not harmful to most plants (except acid lovers). In strongly alkaline soils, however, nutrient-availability problems related to pH result.

The parent material of soils initially influences soil pH. For example, granitic soils are acidic and limestone-based soils are alkaline. However, soil pH can change over time. Soils become acidic through natural processes as well as human activities. Rainfall and irrigation control the pH of most soils. In humid climates, heavy rainfall percolates through the soil. When it does, it leaches basic ions such as calcium and magnesium and replaces them with acidic ions such as hydrogen and aluminum. In arid regions (less than 20 inches of rain per year), soils tend to become alkaline. Rainfall is not heavy enough to leach basic ions from soils in these areas.

Adding sources of organic matter (such as manures and composts) acts to buffer pH and either reduce the pH of alkaline soils or increase the pH of acidic soils. Adding organic matter to soils therefore acts as a general remedy to improve pH.



The Influence of Soil pH on Nutrient Availability



Human activities that increase soil acidity include fertilization with ammonium-containing fertilizers and production of industrial by-products such as sulfur dioxide and nitric acid, which ultimately enter the soil via rainfall. Irrigating with water high in bicarbonates gradually increases soil pH and can lead to alkaline conditions. In most cases changes in soil pH occurs slowly whether human-caused or natural. This is due to the tremendous buffering capacity (resistance to change in pH) of most mineral soils. An exception to this is high-sand-content soils, where buffering tends to be low.

Nutrient availability varies markedly according to pH. This, in fact, is the main reason why pH is so critical. The best pH for overall nutrient availability is around 6.5, which is one reason why this is an optimal pH for most plants. Therefore, maintaining pH close to the ideal level of 6.0 to 7.0 for most plants is important.

Calcium, magnesium and potassium are cation nutrients, meaning they are available to plants in a form with a positive charge. Cations do not adsorb permanently to particles. Other compounds that are more strongly attracted to the cation exchange sites can replace them. This is one way that pH affects nutrient availability. Low-pH soils, by definition, have many of their cation-exchange sites occupied by H+ ions. By default, exchange sites holding H+ ions cannot hold other cations. Therefore, low-pH soils are more likely to be deficient in nutrients such as magnesium, calcium or potassium. If cations are not held by particles, they can leach out of the soil.

Biological Properties

A healthy soil food web supports a consistent release of minerals and nutrients into the soil to support plant growth. In a healthy soil the minerals and nutrients in a soil are locked up in large soil aggregates, these can be broken down by bacteria and fungi in the soil to provide a slow release fertiliser for plant growth. In exchange, plants provide the bacteria and fungi with sugars produced by photosynthesis through their roots. This creates a dynamic and complex food web in the soil which sustains plant growth without any chemical fertilisers.

Soil contains a complex ecosystem of microorganisms that until recently has been little studied. It is often said that a handful of soil has more living organisms than there are people on planet Earth. When the biology in soil is balanced, soil can produce healthy plants season after season. These naturally occurring organisms convert mineral and organic material into nutrients that plants require, creating a symbiotic relationship between plant and soil.

The soil contains a vast array of life forms ranging from submicroscopic (the viruses), to earthworms, to large burrowing animals such as gophers and ground squirrels. Microscopic life forms in the soil are generally called the "soil microflora" (though strictly speaking, not all are plants in the true sense of the word) and the larger animals are called macrofauna.

Soil animals, especially, the earthworms and some insects tend to affect the soil favorably through their burrowing and feeding activities which tend to improve aeration and drainage through structural modifications of the soil solum. In general, they affect soil chemical properties to a lesser extent though their actions indirectly enhance microbial activities due to creation of a more favorable soil environment.

Biological Properties

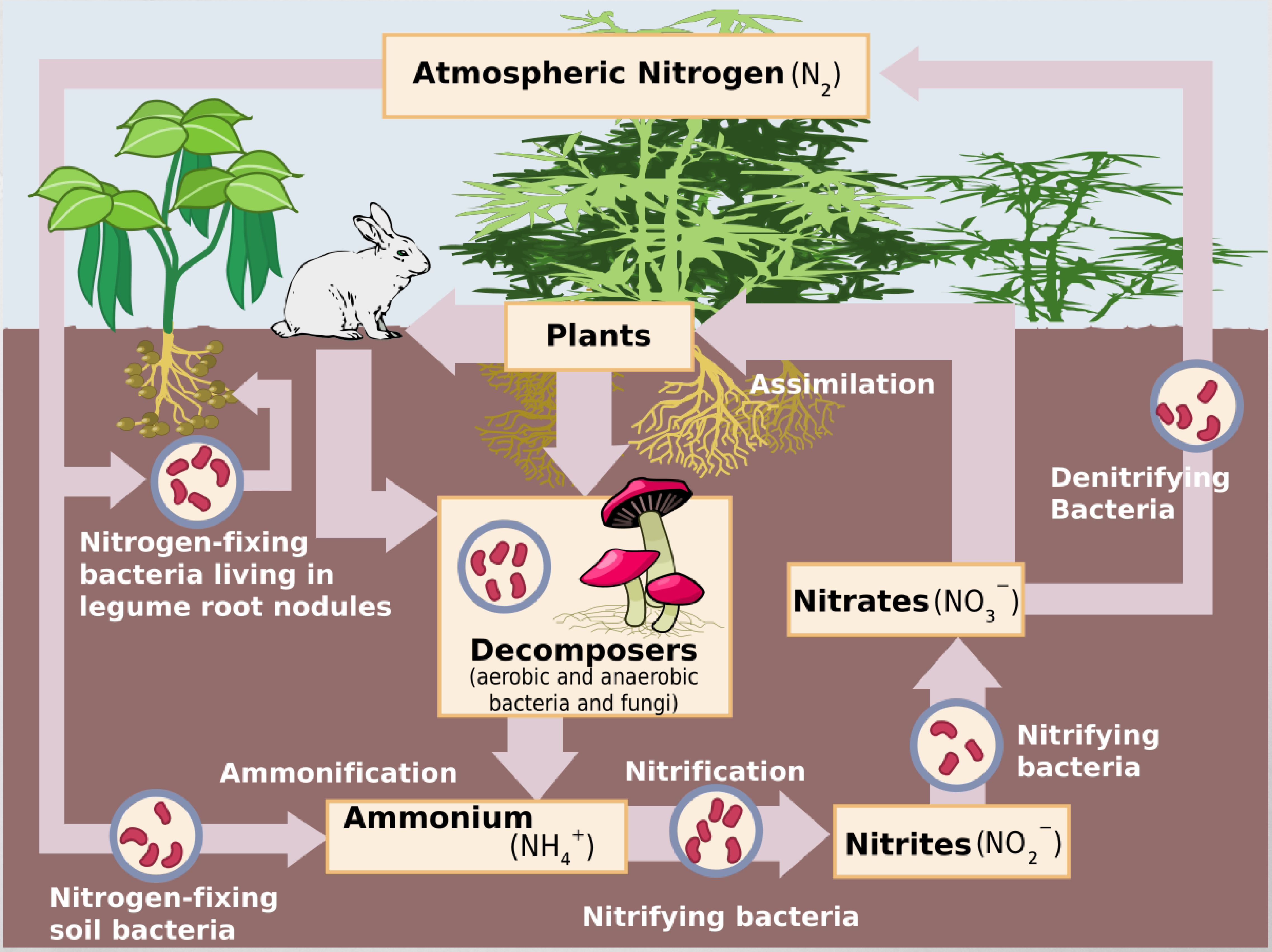
Soil microorganisms occur in huge numbers and display an enormous diversity of forms and functions. Major microbial groups in soil are bacteria, fungi, algae (including cyanobacteria) and protozoa. Soil microbes can occur in numbers ranging up to several million or more in a gram of fertile soil (a volume approximately that of a red kidney bean). Bacteria are the most numerous of the soil microbes. However, It is the soil fungi which contribute the most biomass among the microbial groups. A fungus, Armillaria bulbosa, discovered in the U.S. could turn out to be earth's largest living creature on Earth. The microscopic, branched filaments (called hyphae) of the fungus occupy a 14.8 ha (37-acre) area of land. Careful genetic analysis has shown the filaments constitute a single organism. Scientists estimate that the portion of the fungus they have been able to identify may weigh as much as 100 tons, slightly less than a blue whale. Imagine the biochemical capacity of a soil microorganism this large!

There are complex interaction between soil organisms. Many of these interactions are based around symbiotic relationships where each organism's benefits the other.The most widely recognized example is that between nitrogen fixing Rhizobium bacteria that live in root nodules of legume host plants and exchange with those plants nitrates created from atmospheric nitrogen in exchange for sugars produced by the host plant. Nearly two-thirds of the world's nitrogen supply is from biological nitrogen fixation. Legumes have been used since the beginning of recorded history as "soil improving" crops known as "green manures". Green manuring is the practice of growing a legume species for the sole purpose of returning it to the soil to serve as a source of nitrogen for an ensuing crop.

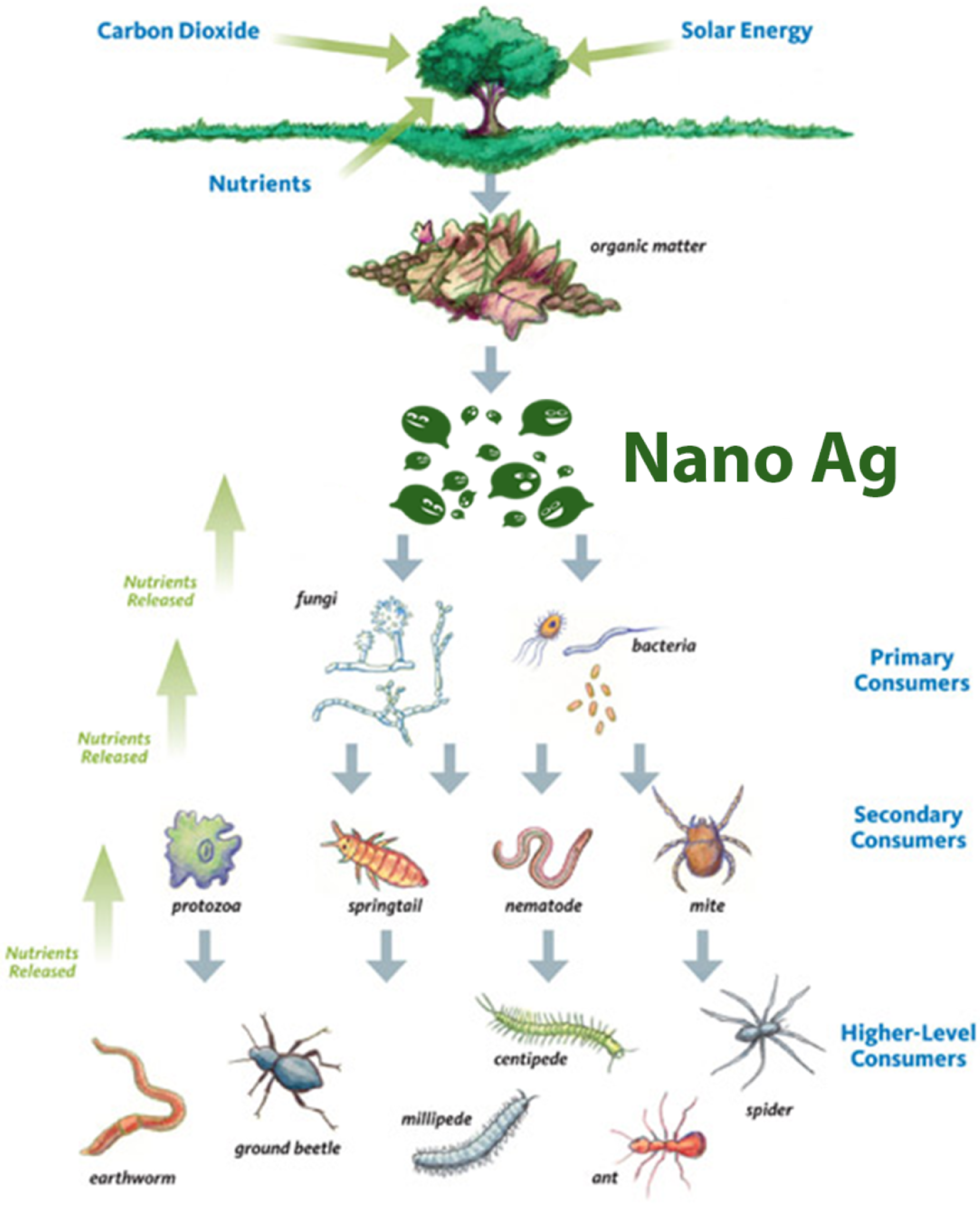
Life in the soil can be organised into trophic levels. At the base of the trophic levels lies the soil microbial population which degrades plant, animal and microbial bodies, and also serves as the food source for some of the levels above it. For example, soil protozoa consume enormous numbers of bacteria and even some fungal spores. These in turn are consumed by still larger soil animals (nematodes, mites, etc.) which in turn are eaten by still larger animals (e.g. worms and insects). Thus, nutrients flow through this microbial food web which lies at the heart of controlling soil fertility and plant productivity in the absence of external inputs such as fertilizers.

Biological Properties

Plants actually tell us a great deal about soil. Certain trees, by how they look above ground, can tell us about soil depth. The presence of trees, such as willows, can tell us about underground water sources. When deep-rooting trees are in sandy soils, they might indicate clay deposits deep below the surface. Thick stems indicate plenty of water, whereas thin stems signify it is dry. The health of specific plants also helps to tell us about pH balance. Strawberries thrive in acidic soil, whereas basilicas prefer alkaline environments, and neither will do as well when planted against these wishes. Weeds and plant pests can indicate deficiencies, as when thistles tell us that iron and copper might be lacking or locked up due to overly acidic soil. Recently burned soils will probably have ferns or blade grasses. Waterlogged soil might have marsh grasses or reeds. Compacted soils will have plants with deep-tapping roots. Weeds are merely symptoms of the actual problems with the system.



Nitrogen cycle in soil food web.



Soil Food web.

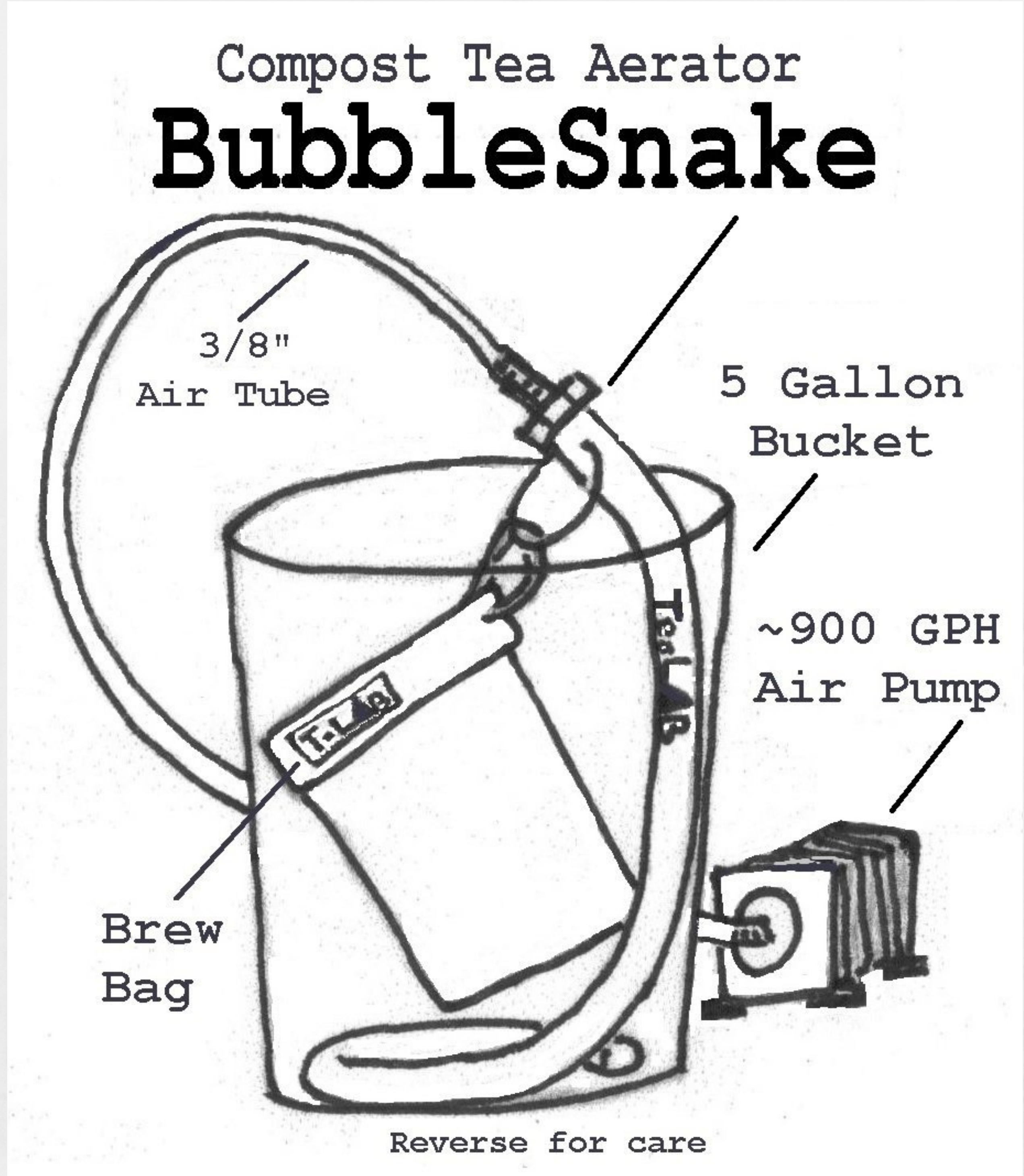
Building Soil

Soil can be created within permaculture farms by using a wide range of techniques including holistic grazing, adding compost and compost teas, using biochar, favouring perennial crops, avoiding tilling soil and practising crop rotation and crop residue mulching. These practices minimize biota disturbance and erosion losses while incorporating carbon rich amendments and retaining the biomass of roots and shoots, all of which contribute to building organic matter in soil and feeding a thriving soil community.

Skilled gardeners pay attention to the soil, and they create a crumbly texture by adding plenty of organic matter. Building soils is a priority. In gardens, this comes from earth-shaping, composting, and mulching, but over large areas, there is more need to work with nature. Soils can be reconditioned by ripping lines to open soils to air and water. The lines should be planted with pioneer species to snuff out weeds, and later, the area should either be chopped, leaving the organic material on the ground, or quickly grazed, with the manure providing nutrients. Repeating this process over a year will create spongy, rich soil. Once the soil has been rehabilitated, practices have to be appropriate, minimizing cultivation, using perennial crops and trees, and cycling livestock through the air so that it is beneficial rather than destructive. Then, we have moved into a permanent and productive system.

Bare soil is detrimental to soil health in general. Agricultural soils that are left fallow or are heavily tilled are exposed to wind and water leading to erosion of the carbon-rich topsoil. Fallow land also fails to accumulate biomass carbon that it would otherwise by continuously growing plants. Tilled, exposed, and eroded soils lead to the breakdown of soil aggregates, allowing formerly stable soil carbon to be released as a carbon dioxide gas. Tillage further undermines soil carbon sequestration by debilitating the growth of mycorrhizal fungi, which are important for the creation of a healthy soil community.

Soil erosion is one of the largest problems on the planet, and soils cannot be created by industry. For permaculture, erosion is an essential problem to address in designs. We are losing tons of soil annually to both wind and water erosion. This can be prevented by adding breaks to slow down wind, and planting plenty of trees and fast-spreading grasses so that their roots can stabilize the soil. Trees also soften the impact of rain, and we can additionally create diversions and catchment systems to stop water flows that carry topsoil away. We also have to assess the soil condition, slope, and forests on sites and design with erosion prevention in mind. We also must think through roadways and regulate animal grazing. The problems that are causing erosion are recognizable and solvable through good design.



Compost tea maker. An assortment of compost, seaweed, nutrient rich plants and manures can be added to the brew bag. The same design on a bigger scale can be used to create compost teas for large scale farms.

Organic Tea Recipes

For Trees: Fungal dominent compost - Brew time 24-48 hours

Barrel Size	Compost	Kelp	Fish Hydrolysate	Hydra-hume	Vegetable Oil	Flour
15 Gallon	3-4 lbs.	4 oz.	4 oz.	4 oz.	1/2 cap	1/2 cup
30 Gallon	6-7 lbs.	8 oz.	8 oz.	8 oz.	1 cap	1/2 cup
50 Gallon	7-8 lbs.	12 oz.	12 oz.	12 oz.	1 cap	1/2 cup
100 Gallon	10-12 lbs	24 oz.	24 oz.	24 oz.	1 cap	1/2 cup

For Lawns: Bacterial dominent compost - Brew time 18-24 hours

Barrel Size	Compost	Molasses	Kelp	Fish Hydrolysate	Vegetable Oil	
15 Gallon	3-4 lbs	4 oz.	4 oz.	4 oz.	1/2 cap	
30 Gallon	6-7 lbs	8 oz.	8 oz.	8 oz.	1/2 cap	
50 Gallon	7-8 lbs	12 oz.	12 oz.	12 oz.	1/2 cap	
100 Gallon	10-12 lbs	24 oz.	24 oz.	24 oz.	1 cap	

If you're using domestic water, aerate the water for 15-20 minutes prior to adding compost bag to dechlorinate

Recipes for making different compost teas.