Farmer Education Program (PEPA) Resource Guide

Soil Fertility and Irrigation Management

Agriculture & Land-Based Training Association (ALBA)

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Basics of Organic Soil Fertility

By Eric Sideman, Ph.D. 2006

Good soil and land husbandry involve the active management, by farmers and other land users, primarily of irrigation and rainwater, vegetation, terrain and bed preparation, plant nutrients and soils, including their inherent biota. It is exercised at a variety of scales, from a small garden to a large crop production field (Shaxson, T.F. 1993).

The encouragement of better soil and land husbandry and the underlying philosophy suggest that conservation of water and soil is best achieved by promoting local land management strategies that benefit both the land user and the soil. Good soil strategies (which may include planning of more-appropriate land uses and their management) enhance the soil's regenerative capacities to improve the vitality and resilience of the total soil ecosystem. Good land husbandry manages soil organic matter and creates and maintains favorable soil structure, rather than merely preventing physical loss of water and soil. It also embraces a better matching of soil and land uses with proper management practices, which help maintain soil and land ecosystem and water and nutrient cycles (Shaxson, T.F. 1993).

There are two basic approaches to soil fertility management. The first is to provide required nutrients to each crop in a soluble form that plants can use immediately. In other words, feed the plants directly. This approach can accurately meet a crop's needs. During the twentieth century scientists learned how to make fertilizers from synthetic chemicals and how to provide plants with exactly what they need.

The alternative approach to fertilization is building and maintaining stable nutrient levels in the soil using natural materials. The decomposition and natural chemical breakdown of these materials put the nutrients into forms that are available to crops. Organic farming and gardening is based on this second approach. Robert Rodale, one of the fathers of organic farming and gardening, is often quoted as saying, "Feed the soil and it will feed the crop." Organic farming is really all about taking care of the soil. Good crops can be grown using the former method of maintaining fertility with synthetic chemicals, but the great disadvantage of this approach is that it does nothing to improve the soil and the long-term productivity of our farms and gardens. In fact, the longer synthetic chemical fertilizers are used, the more dependent the soil becomes on them, because soil microbes have no organic matter for food and they disappear. I have heard such soils accurately referred to as dead.

The advantage of the organic approach is continued improvement of soil fertility, protection of natural physical and biological processes in the soil, and minimal environmental disturbance, because organic sources of nutrients are less likely to leach or run off and contaminate ground and/or surface water. Building long-term soil fertility is the goal of organic farming and gardening. The weakness of the organic approach is that it is not as exact a science as providing soluble nutrients, and determining precise applications of organic soil amendments is difficult, especially when microbes are limited by cold, wet or dry weather. But we put up with this challenge to protect our environment and take care of our soil.

Another advantage of the organic approach is that growers can certify their produce as **organic** under the U.S. Department of Agriculture, where they must comply with certain standards when managing their farm's soil. A farmer cannot apply chemically processed fertilizers or amendments for three years prior to certification. Some examples of materials that

are prohibited are urea, sewage sludge, and synthetic fertilizers. Instead, farmers must rely on compost, green manures, and mined mineral products to maintain soil fertility. For a complete list of prohibited and allowed substances, go to the USDA's National Organic Program's Web site (**http://www.ams.usda.gov/nop/NationalList/FinalRule.html**). (Maintaining Soil Fertility Under an Organic Management System By Melissa Van Tine, 2003)

In addition, to maintain organic certification, a grower is required to document his or her soil fertility plan, which includes a five-year farm history with details about soil quality, pest management, inputs, tillage, crops, and rotations for farm fields.

In the following pages you will find an overview of soil quality indicators, including important information that will help you create a soil fertility plan to be able to obtain organic certification.

Learning Objectives

1. **Recognize soil quality characteristics**
2. **Test for 10 important soil quality indicators in assessing soil quality: Soil Tilth, Soil Compaction, Soil Workability, Soil Biodiversity, Soil Organic Matter, Soil pH, Crop Health and Vigor, Water Infiltration, Water Holding Capacity, Soil Erosion**
3. **Create a Soil Fertility Plan**

Introduction

Modern agricultural practices have led to significant increases in crop production in the last 50 years. However, we are becoming more aware of the impact of these changes on the wider environment and the soil itself. Negative soil impacts have forced us to work towards greater sustainability for improved soil fertility and management. Soil management practices in organic farming have been developed to measure soil quality in order to increase awareness of the state of our soils from season to season. In the following section we have provided an overview of soil quality indicators, which includes important activities and data that will help you construct a soil fertility plan and improve and maintain optimal soil quality.

What does soil consist of?

Soil is a natural body made up of minerals, air, water and organic matter. In most soils, the total volume of matter is: 45% minerals, 25% air, 25% water and 2% -5% organic matter.

The most fertile soils have 5% organic matter and are usually dark in color.

Soil Quality

Optimal soil quality does the following actions:

- Sustains biological activity, diversity, and productivity;
- Regulates and partitions water and solute flow;
- Filters, buffers, degrades, immobilizes, and detoxes organic and inorganic materials, including industrial and municipal by-products and atmospheric depositions;
- Stores and cycles nutrients and other elements within the earth's biosphere; and
- Provides support for socioeconomic structures and protection of archeological resources

What are the features of good soil?

Any farmer will tell you that good soil:

- feels soft and crumbles easily
- drains well and warms up quickly in the spring
- does not crust after planting
- soaks up heavy rains with little runoff
- stores moisture for drought periods
- has few clods and no hardpan
- resists erosion and nutrient loss
- supports high populations of soil organisms
- has a rich, earthy smell
- does not require increasing inputs of fertilizers for high crop yields
- produces healthy, high-quality crops

(ATTRA 2004)

Soil Quality Indicators

Farmers need reliable methods to assess soil quality to make management decisions that maintain long-term soil productivity. Therefore, a set of soil quality indicators has been identified to assess the impact of soil management and to help farmers evaluate the condition of agricultural soils.

Soil Quality Indicators to be discussed in the section include:

1) **Soil Tilth**
2) **Soil Compaction**
3) **Soil Workability**
4) **Soil Biodiversity**
5) **Soil Organic Matter**
6) **Soil pH**
7) **Crop Health and Vigor**
8) **Water Infiltration**
9) **Water Holding Capacity**
10) **Soil Erosion**

1) Soil Tilth

Tilth refers to the physical condition, texture or structure, of the soil as it influences plant growth. A soil with good tilth is very **porous** and allows rainfall to **infiltrate** easily, permits roots to grow without obstruction, and is easy to work. Tilth is also related to bulk density, which is the weight per unit volume of soil.

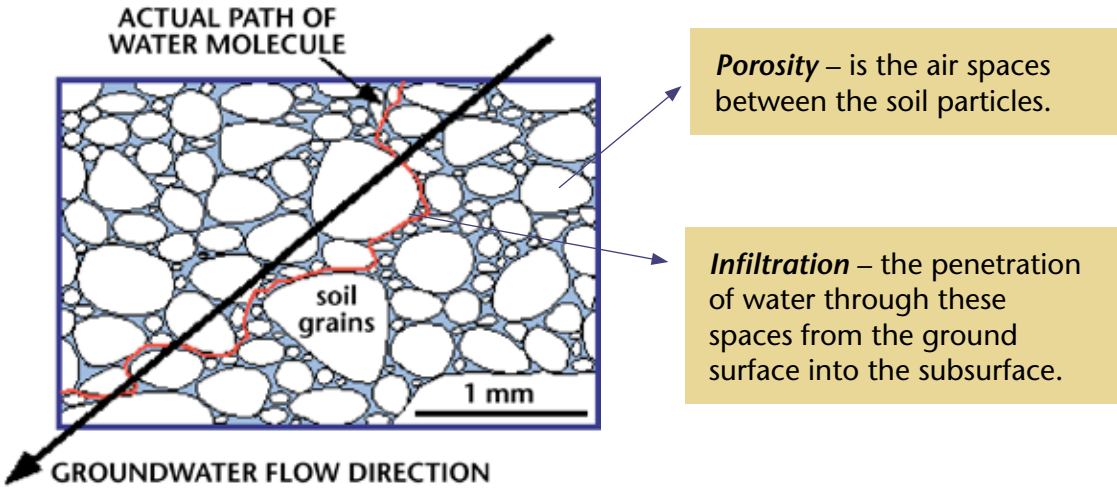
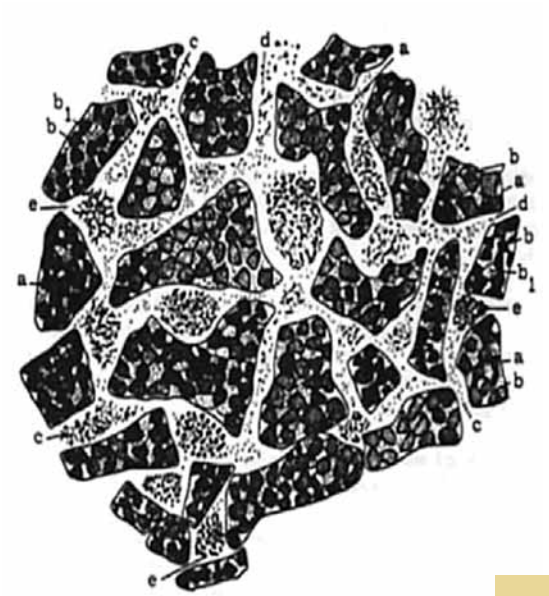


Figure 1. Soil tilth showing water infiltration.

Soils with lower bulk density, such as loam and sandy loam soils, tend to have higher porosity and better tilth. Such soils also have an even distribution of large and small pores, allowing them better aeration, water holding capacity and infiltration rates and making it easier for roots to grow through. High *aggregate* stability preserves the larger pores by preventing clogging with loose particles.

Soil Aggregates are soil particles (i.e., sand, silt and clay) held together in a single mass or cluster. Stable soil aggregates are formed from the binding action of humus and other organic matter components, the activities of soil organisms, and the growth of plant roots in the soil.



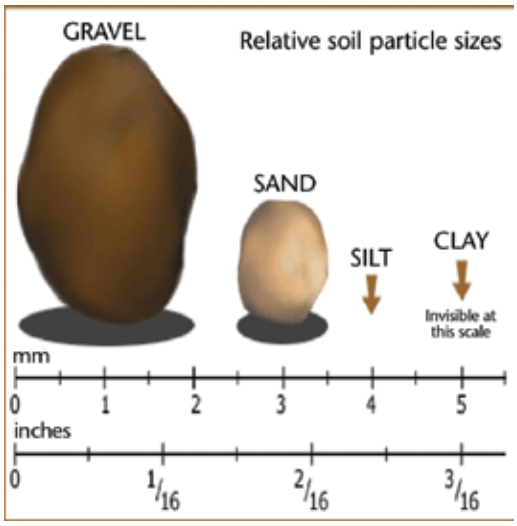


Figure 2 and 3. Soil Aggregates.

Sand is the largest soil particle and clay is the smallest. Sand is mostly the mineral quarts which contains no plant nutrients, and cannot hold nutrients or water

Aggregate stability — the ability of natural aggregates to resist breaking apart as a consequence of wetness or tillage.

Soils with ***poor aggregate stability*** are evident when individual aggregates break apart easily. Soils with ***high aggregate stability*** do not break apart easily when wet, tilled or otherwise disrupted; therefore, these soils are better able to resist erosion since the aggregates are heavier than their individual particle components. ***High aggregate soil stability*** allows for increased water entry, air flow and water-holding capacity.

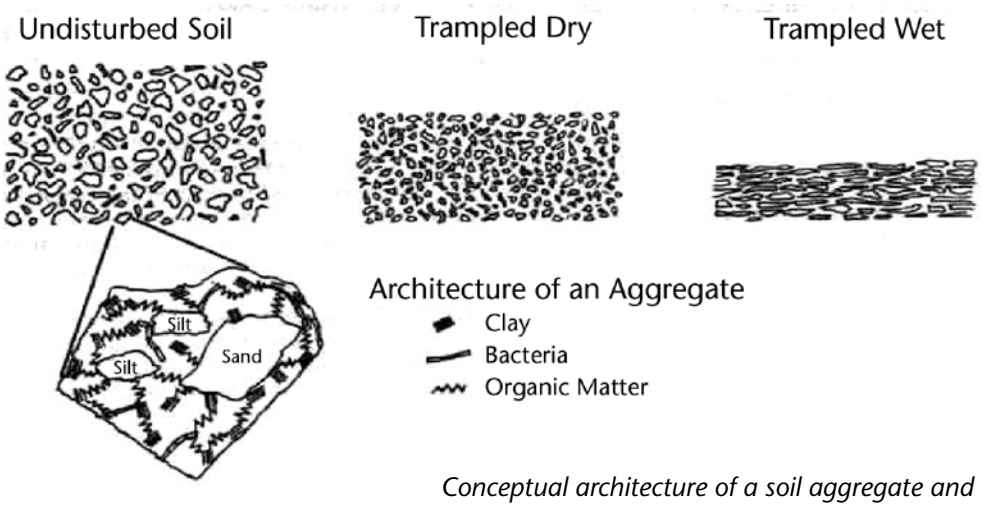


Figure 4. Aggregate Stability.

Conceptual architecture of a soil aggregate and the changes in soil aggregate structure caused by trampling under wet and dry conditions.

Soil Consistence refers to the feel of the soil and the ease with which a lump can be crushed by the fingers.

Determination of Soil Tilth in the Field

In the field, the percentages of sand, silt, and clay particles in a soil are estimated by feel. The soil is rubbed between the fingers and the thumb and an estimate of the amount of the various separates present is made based on the degree to which the characteristic properties of each are expressed. This process of estimation requires skill and experience, but accuracy can be improved by frequent checks. Dry soil feels different from moist soil, due in part to the fact that soil particles tend to aggregate together upon drying. It is best to moisten dry soil when making field estimates of soil texture.

The more important characteristics of the various textural classes of soils which are of value and which can be recognized by feel and/or determined by laboratory analysis are as follows:

- ***Sands*** are loose and single-grained (that is, not aggregated together). They feel gritty to the touch and are not sticky. Each individual sand grain is of sufficient size that it can easily be seen and felt. Sands cannot be formed into a cast by squeezing when dry. When moist, sands will form a very weak cast (as if molded by hand) that crumbles when touched.
- ***Sandy Loams*** have less sand and more silt and clay than loamy sands. Many of the individual sand grains can still be seen and felt. There is sufficient silt and/or clay to give coherence to the soil and less easy to break under careful handling.
- ***Loam*** is a soil material that is medium-textured. It feels as though it contains a relatively even mixture of sand, silt, and clay because clay particles, with their small size, high surface areas, and high physical and chemical activities, exert a greater influence on soil properties than does sand or silt. Loam tends to be rather soft and friable. It has a slightly gritty feel, yet is fairly smooth and slightly sticky and plastic when moist. Casts formed from such soils can be handled quite freely without breaking.
- ***Clay Loam*** consists of soil material having the most even distribution of sand, silt, and clay of any of the soil textural grades. But it feels as though it possesses more clay than sand or silt. Sticky and plastic when wet, it forms casts that are firm when moist and hard when dry. The moist soil will form a thin ribbon that will barely sustain its own weight when squeezed carefully between the thumb and fingers.
- ***Clay*** is the finest textured of all the soil classes. Clay usually forms extremely hard clods or lumps when dry and is extremely sticky and plastic when wet. When containing the proper amount of moisture, it can be "ribboned out" to a remarkable degree by squeezing between thumb and forefinger, and may be rolled into a long, very thin wire.
- ***Organic Soils*** are made up of plant and animal remains that have accumulated, in varying stages of decomposition, in an environment that does not allow decay of the materials to take place rapidly. Such an environment may be found in some swamps, marshes, and lakes, and rarely in drier, more upland environments where the ecosystem is so productive that plant remains accumulate at extremely high rates. Muck, peaty muck, mucky peat, and peat are terms used in place of textural class names for organic soils. Muck consists of highly decomposed remains of plants and other organisms. Peat consists of relatively raw, less well-decomposed organic materials. Peaty muck and mucky peat are intermediate in decomposition. Mineral soils, as described in earlier paragraphs, are not dominated by organic materials, but consist primarily of sand-, silt-, and/or clay-sized particles of minerals or rock fragments. If you encounter a soil material that has been designated mucky sand or other such mixed name, it indicates that the soil is a mineral soil having a higher than ordinary content of organic matter (say, 10% or so by weight), but not high enough to treat the soil as an organic soil (muck, peaty muck, etc.).

Table 1. Classification of Soil Texture.

Texture	*Sand*	*Sandy Loam*	*Loam*	*Clay loam*	*Clay*
Touch	Rough	Rough	Rough	Soft	Clods
Internal drainage	Excessive	High	Good	Regular	Regular or poor
Available water for plants	Low	Medium Low	Medium	High	High
Tilth	Easy	Easy	Easy	Medium	Difficult
Wind erosion	High		Medium	Low	Low

The Mucky Hand Test to Identify Soils

To find out what type of soil it is, you will need to carry out this simple mucky hand test:

1. Add enough water to the soil sample so that you can knead it for a few moments in your hand.
2. Try and make the following shapes (**Table 2**). The shape you get most easily will tell you what type of soil you have.

The final shape you get is the soil texture, for example, if a worm shape can be made but it breaks if bent, it is a loam.

Table 2. Identifying Soil by Shape

	Shape	**Type of soil**
	Cone	Sand
	Ball	Loamy sand
	Worm	Loam
	Bent Cracked Worm	Clay Loam
	Smooth Bent Worm	Clay

Rating the Soil Tilth: 0–10

0 = least desirable. Soil breaks apart completely (too sandy) or can bend in a circle without breaking (too much clay)

5 = soil has some crumb structure. Individual crumbs break under only slight pressure and are much more fragile after wetting.

10 = Soil is mucky and crumbly with a definite granular loam structure. Aggregates maintain their shape under moderate pressure even when wet, but still can be broken between fingers.

Recommended Management

Soil structure and tilth are impacted directly by soil management. A seasonal or yearly assessment of this indicator may show whether current management practices are helping or hindering the free movement of air and water through the soil. Good management of organic matter such as compost and disking in of cover crops to encourage earthworm activity and microbial decomposition will improve soil tilth and structure. Operations that allow erosion and compaction of the soil, such as leaving a field bare over winter or working a soil when it's too wet, will result in poor soil tilth and structure.

2) Soil Compaction

Compaction occurs when farm machinery passes over the same area of soil repeatedly, or, it can occur from only one pass, if it is made when the soil is wet. The weight of the equipment, the number of trips across the field, and the type of soil determine the degree of compaction. The more intensely the soil is tilled, the more likely it is to be compacted.

Compaction that restricts crop roots to the upper few inches of soil layers increases production costs by increasing runoff, erosion, seedling mortality and susceptibility to crop damage during periods of drought. Improving compacted soils are frequently not cost effective so one of the best strategies is to avoid creating conditions which may cause compaction.

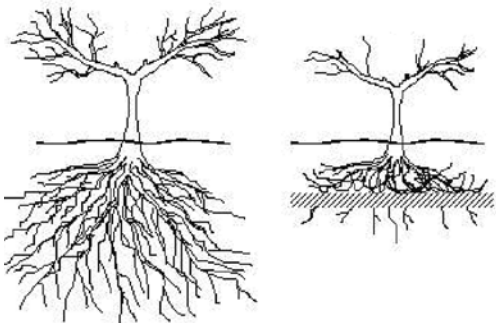


Figure 5. Compaction that Restricts Crop Root Growth.

The volume available for plant root development can be seriously reduced by the presence of compacted, subsurface layers. Compaction can severely restrict air and water movement in the soil. Compacted soil properties also limit microbial activity and the ability of earthworms and other organisms to live in the soil.

Basic Test for Soil Compaction

Materials needed: Wire flag

Hold the wire flag near the flag end and push it vertically in the soil at several different locations in the field. Record the depth at which it bends due to resistance in the soil.

Soil compaction:

- Reduces the air spaces between the soil particles,
- Makes water drainage difficult;
- Impedes root development,
- Makes it difficult for soil organisms like earthworms to move.

Rating Soil Compaction: 0–10

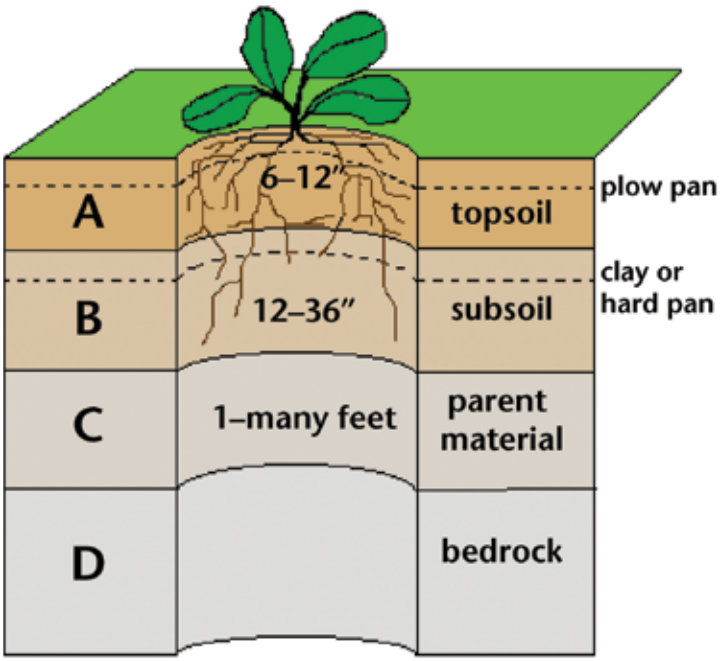
0 = least desirable. The flag bends readily. Plant roots that turn horizontally indicate a hardpan.

5 = Moderate. Some restriction to a penetrating wire flag, some root growth restrictions.

10 = Preferred. The wire flag can penetrate all the way into the topsoil beyond the tillage layer and into the subsoil without bending.

Recommended Management
Fewer trips across the field can reduce compaction. Compaction can be limited by not working the ground or avoiding heavy grain trucks and manure spreaders when the soil is too wet. The sliding action of tillage equipment over the same layer of sub-soil can also create compaction in the form of a hardpan or plow pan just below the tilling zone.

Certain types of tillage equipment such as moldboard plows and disk harrows can contribute to a plow pan. This equipment exerts a downward force on the soil as it lifts and turns. This force smears clay across the tops of pores and makes an impermeable layer of soil. Physically breaking through a deep compacted layer with sub-soiling equipment can help counteract deep compaction. Deep chiseling (ripping) can alleviate some compaction problems, but in some cases only for the short term.



A **hardpan** is a highly compacted, impermeable layer just below the topsoil. When a farm machine ploughs the topsoil, its weight compacts the soil below it, making it very difficult for water to infiltrate, roots to develop and earthworms to move around.

In the short term, ploughing makes the topsoil more aerated and improves drainage; however, in the long term, its weight compacts the soil below it.

Figure 6. Hard Pan and Plow Pan

Incorporation of cover crops and other organic residues can help build soil organic matter, which can be important in counteracting compaction. The natural cycle of freezing and thawing can break up a plow pan. Planting deep rooted forages such as alfalfa and eastern gamma grasses can also help break up compacted layers. Earthworms can eat through compacted layers if the soil is wet, primarily in clay and silty soils

3) Soil Workability: Is the Soil Worked Easily?

Workability is the ease with which a field is prepared for planting. A workable soil is one that: Does not form heavy clods (too much clay) or dusty powder (too much silt) when tilled; breaks up evenly to form a good seedbed; requires a minimum amount of tractor energy to till.

Workability of the soil is important to know when determining how easily a seedbed is prepared and how well water infiltration and soil structure are in a desirable state.

Basic Test: Soil Workability

Materials needed: Notebook for tillage records

The procedure to measure soil workability is to keep good records of:

1. The horsepower and gear needed to complete tillage
2. The number of trips across the field
3. Your estimate of the total fuel consumption for seedbed preparation and planting

Rate Soil Workability: 0–10

0 = Least desirable. Tillage requires a high horsepower and low gears for primary tillage, high fuel consumption, and many cultivation passes to create a seedbed, or good seedbed preparation cannot be accomplished.

5 = Moderate. Tillage requires a medium amount of power and number of trips to prepare a good seedbed.

10 = Preferred. Tillage is noticeably easy and requires the minimum amount of tractor power, fuel consumption, and trips across the field to prepare a good seedbed. Primary tillage can be done in a relatively high gear.

Recommended Management

Provide adequate organic matter to help maintain soil tilth, and reduce tillage to avoid compaction.

4) Soil Biodiversity

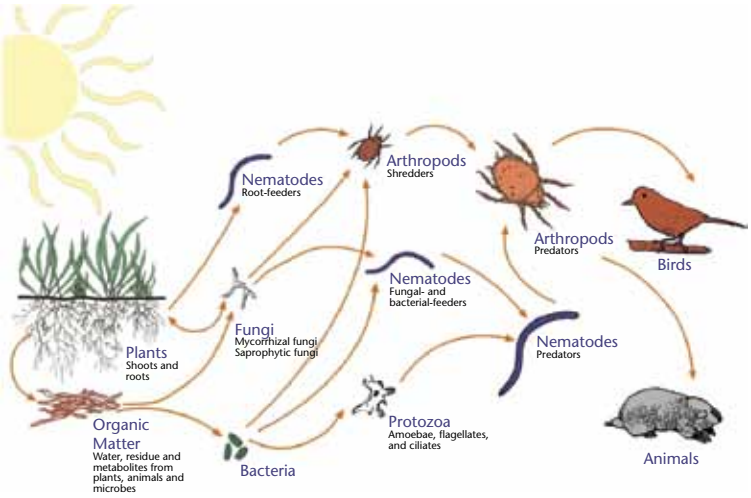


Figure 7. Soil Food Web.

Soils have great biodiversity; it is a complex ecosystem supports a large variety and abundance of life. Many different kinds of organisms are represented in the soil. Each species of soil life contributes to organic residue decomposition and nutrient cycling within the soil. If many different kinds of organisms are present in the soil, then nutrients are more likely to continue to be available for plant growth. Greater diversity and abundance of soil organisms also provide conditions that can suppress pests and diseases.

Beetles, springtails, mites, earthworms, spiders, ants, nematodes, millipedes, rodents, reptiles, snails, and other soil creatures are important "keystone" participants in the soil food web and have long been recognized as an important part of healthy agricultural soils.

Earthworms are particularly important for soil quality. Some species create deep burrows, while others live just under the litter layer at the soil surface. The movement of earthworms through the soil creates passageways that increase aeration and water infiltration. Some burrowing forms ingest large amounts of organic material and mineral soil and excrete them as casts at the soil surface.

An acre of living topsoil contains approximately:
900 pounds of earthworms,
2,400 pounds of fungi,
1,500 pounds of bacteria,
133 pounds of protozoa,
890 pounds of arthropods and algae and even small mammals.
(Pimental 1995), (ATTRA 2004).

These organisms help aerate the soil, improve water infiltration and cycle positive nutrients into the soil.

Earthworm casts contain more enzymes, bacteria, organic matter, and available plant nutrients than the surrounding soil. Their lubricating secretions bind soil particles together and help increase aggregate stability. Earthworms are particularly important in no-till systems as they are one of the main engines for soil mixing, which is essential for nutrient cycling and organic matter decomposition

Figure 8. Topsoil

Basic Test: Soil Biodiversity

Materials needed: shovel, watch

Follow this procedure to measure the soil's biodiversity:

1. Dig out a shovel of soil down to at least 6 inches.
2. Examine the soil for an exact amount of time (2-4 min.).
3. Count the total number of individual organisms you see. Note: keep in mind that bacteria and fungi are too small to see but are also soil organisms.
4. Then notice the top of the soil and count the number of worm burrows you see.
5. Dig out another shovelful of topsoil and count the earthworms in this section of soil.

Rating Soil Biodiversity: 0–10

0 = Least desirable. Almost no moving organisms in 2–4 min. No evidence of worm holes or burrows.

5 = Moderate. One or two individuals of at least two kinds of soil organisms are found in the sample after 2–4 min. of searching. About 3 earthworms are present and only a few burrows in the soil are seen.

10 = Preferred. Several individuals of at least four different types of soil organisms are seen. More than 5 earthworms can be counted in a shovelful of topsoil, and there is abundant evidence of earthworm casts and burrows on the soil surface.

Recommended Management

Management directly affects soil organism populations by providing a source of food. Incorporate more surface residue (organic matter, cover crops etc), which protects and feeds soil, can increase biodiversity including earthworm populations.

5) Soil Organic Matter

Organic matter is formed when **plant residue** from a previous crop or added organic material such as manure or straw decomposes over time. When decomposition is active, soil organic matter will be in all stages of breakdown, from recognizable plant parts, to individual plant fibers, to dark-staining humus. Soil organisms decompose plant residue and recycle it into many different forms that benefit the soil. Most of the decomposition that takes place in soils is due to microbial activity. As larger soil organisms consume organic residue, they break it down into smaller pieces which allow bacteria and fungi to work more efficiently.

Figure 9. Plant Residue

Plant residue is the plant material that remains after the harvest, including leaves, stalks, and roots.

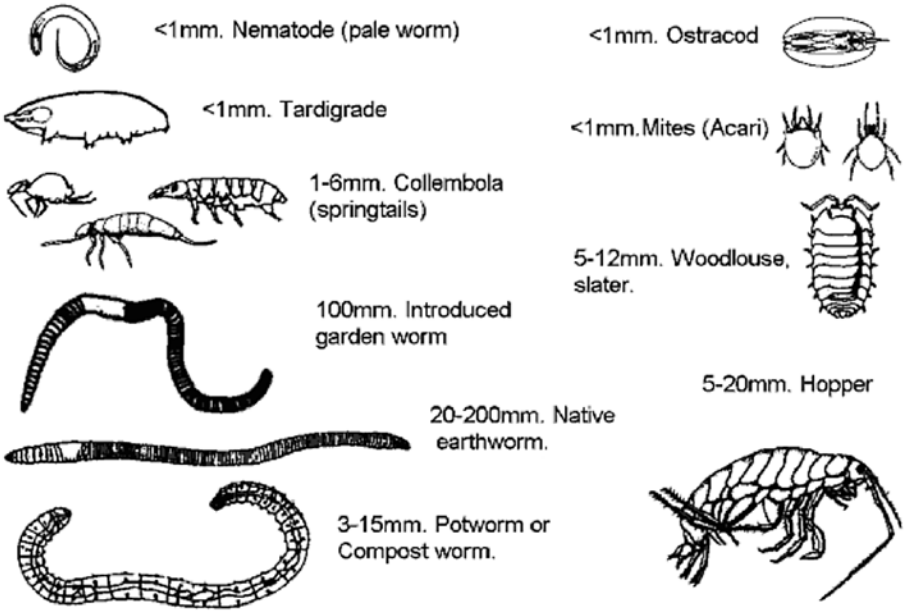
In the photo to the left, the corn residue is being used a mulch to protect the next crop.

Bacteria, fungi and other microscopic organisms decompose the dead plant residue and increase the organic matter contained in the soil. This is called **microbial activity**.

Active decomposition of plant residues is a good indicator that the biological community is thriving in the soil. When no visible residue is present, this suggests that insufficient residues were produced and returned to the soil. Too much residue present indicates that the soil's organisms are unable to decompose the material. Residues in various stages of decomposition are most favorable since the larger pieces help provide tilth and structure to the soil, while smaller pieces are used as food for soil micro-organisms.

Organic matter is important to soil quality because it:

- Represents the principle sources of Nitrogen and Sulfur (and much of the Phosphorous) for crops.
- Increases the nutrient-holding capacity (soil cation)
- Yields decomposition products which glue soil particles into aggregates to improve soil structure, water infiltration and tilth
- Provides a food source for a diverse population of soil organisms to promote nutrient recycling, air and water movement within the soil



Microorganism activity is carried out by organisms that can only be seen in a microscope. These are the organisms that decompose organic matter.

Figures 10 and 11. Microorganisms

Farmers recognize that organic matter is critical to many important functions in the soil such as infiltration, good tilth and nutrient cycling. They associate dark soil color with thickness of plow layer, water storage, drought tolerance, seed bed workability, and with soil fertility factors such as availability of plant nutrients.

Basic Test: Determining Presence of Organic Matter

Materials needed: Shovel, Squirt bottle with water

Follow this procedure to determine amount of organic matter present in the soil.

1. Dig down to at least 6 inches
2. Break the soil apart with your finger to examine the soil for organic residues
3. Look for evidence of organic residue in various stages of decomposition.
4. Put your nose close to the soil and note the smell
5. Lightly moisten some soil with the squirt bottle.
6. Rub this soil between your fingers and see if it leaves a dark stain that is difficult to remove.

Rating the presence of organic matter: 0 – 10

0 = Least desirable. Organic residue on or in the soil does not decompose for a long period of time; there is a sour, muck like smell in the soil; and the soil does not stain the fingers.

5 = Moderate. A substantial amount of undecomposed material from the previous crop is present; there is no distinct smell in the soil; and there is only slight straining of the fingers.

10 = Preferred. Organic residue from the previous crop is present in the soil in various stages of decomposition; freshly dug soil has a sweet, earthy smell; fingers are darkly stained after rubbing soil between them.

Recommended Management

Organic matter can be increased by:

- Adding composted animal manures to the soil,
- Reducing depth and frequency of tillage,
- Leaving straw and residues from cover crop on the surface whenever possible
- Planting cover crops on ground that is usually fallow
- Growing high residue crops, especially those with dense root systems such as small grains and corn.
- Employ rotations that include hay crops

To protect soil from the erosive impacts of rain, incorporate surface plant residues. When organic residue is distributed through the topsoil, it slows the flow of surface water into the soil and reduces erosion by water runoff.

6) Indicator: Soil pH

The pH of a solution is a scientific measurement that describes how acidic (acid) or alkaline (basic) a solution is. It is important to manage the pH of the soils since it can affect the plant's ability to take up nutrients and support the microbial activity in the soil that affects the decomposition processes needed for plant nutrition.

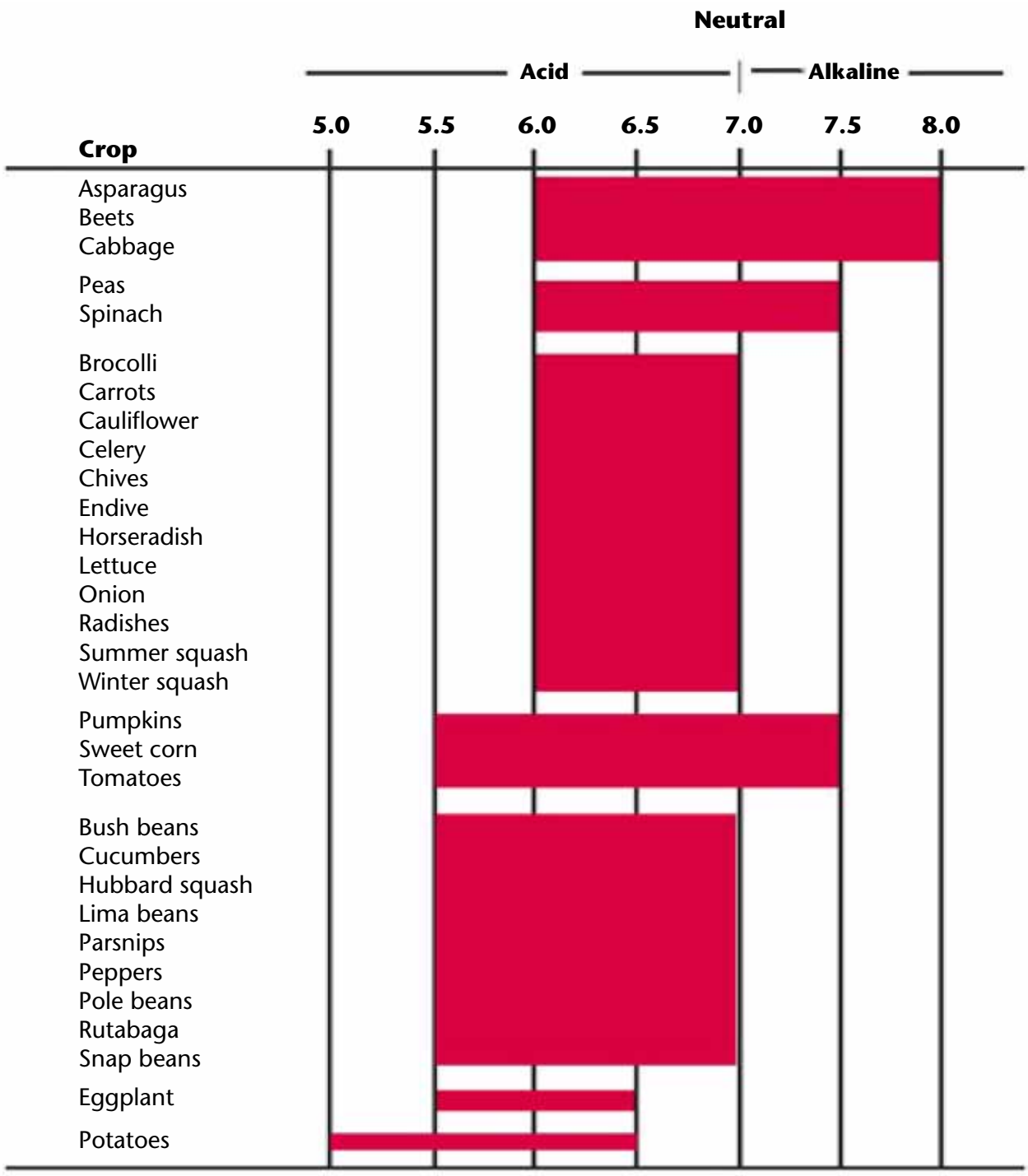
The most common classes of soil pH are:

Extremely acid	3.5 – 4.4
Very strongly acid	4.5 – 5.0
Strongly acid	5.1 – 5.5
Moderately acid	5.6 – 6.0
Slightly acid	6.1 – 6.5
Neutral	6.6 – 7.3
Slightly alkaline	7.4 – 7.8
Moderately alkaline	7.9 – 8.4
Strongly alkaline	8.5 – 9.0

Most vegetable crops prefer a neutral pH between 6.6 and 7.3 as most plant nutrients are readily available in this range. However, some plants have soil pH requirements above or below this range.

It is important to test the pH level of your soil to ensure that meets the needs of the crops you are growing. **Table 3** below shows the appropriate pH level of common crops. Knowing the soil pH is also a good guide for predicting which plant nutrients are most likely to be deficient in the plant. If a pH test, for example, reflects a low soil pH of 5.0 (very strongly acid), there will be low availability of potassium, ammonium, calcium, magnesium, aluminum. As a result, plants not normally accustomed to low pH, will start to show nutrient deficiency symptoms that correspond to the lack of nutrients. At a high pH of 7.8 or more, calcium and magnesium are abundant and available to the plant. However, the soil may have an inadequate availability of aluminum, iron, manganese, copper, zinc, and especially phosphorus and boron. Again, plants not normally accustomed to high pH, will show deficiency symptoms that will correspond to the lack of nutrients that are missing.

Table 3: Appropriate pH Levels of Common Crops.



The pH value influences the amount of positively or negatively charged nutrients in the soil that become soluble or available for uptake by the root system. The net ability of a soil particle to hold, retain and exchange positively charged nutrients is referred to as Cation Exchange Capacity (CEC).

Cation-Exchange Capacity is defined as the degree to which a soil can adsorb and exchange cations.

- Cation—a positively charged ion (NH_4^+, K^+, Ca^{2+}, Fe^{2+}, etc...)
- Anion—a negatively charged ion (NO_3^-, PO_4^{2-}, SO_4^{2-}, etc...)

Soil particles and organic matter have negative charges on their surfaces. Mineral cations can be adsorbed into the negative surface charges or the inorganic and organic soil particles. Once adsorbed, these minerals are not easily lost when the soil is leached by water. They also provide a nutrient reserve available to plant roots. These minerals can then be replaced or exchanged by other cations (i.e., cation exchange).

Soil with a high cation-exchange capacity is better able to hold and retain charged nutrients, making it easier for the plant roots to get the nutrients the plant needs. Adding organic matter increases the cation-exchange capacity level and thus help the plants to access nutrients in the soil.

The Cation Exchange Capacity of soil particles also has the ability to hold and retain charged nutrients against leaching. While both negative anions and positive charged cations are present, negative charged anions usually dominate. When there is a dominate amount of negatively charged anions in the soil, other negative anions will not bind to negative surface charges and thus are more subject to leaching. Nutrients susceptible to leaching include:

Nitrate (N03-) Chloride (Cl-) Sulfate (S04-) Phosphate (H2P04-)

Basic Test for Soil pH

A variety of kits and devices are available to determine the pH in the field. The methods include: dyes, paper strips, glass electrodes.

Procedure:

1. Select 3 test sites; places from which you want to collect soil.
2. Dig approximately 6 inches down into the area and place the bottom half of the sample into the plastic bag and label according to the site.
3. Place one tablespoon of soil from the collection bag into a small plastic cup. Add ¼ cup of distilled water.
4. Swirl the soil and water mixture three times.
5. Place the edge of a 2-inch piece of pH Hydrion paper into the mixture.
6. Observe the color change of the pH paper.
7. Try to match the resulting color to the colors listed on the outside of the pH Hydrion paper package.
8. The colors match with a correlated pH number. This number is the pH value of the soil.
9. If the number is less than 7, the soil has an acidic nature.
10. If the number is more than 7, the soil has a basic nature.
11. Repeat the procedure or test by gathering soil from a different area and testing.
12. Compare your results to see if there are any differences in the pH of different areas tested.

13. Sprinkle a small amount of the soil sample on a white piece of paper or on a white index card.
14. Using the magnifying lens, look for the shape and texture of the soil particles.
15. Repeat steps #11 and #12 with soil from each collection site.
16. Compare your results to see if there are any differences in the different soil samples.

Recommended Management

When adjusting the pH, it is important to know the crop's pH requirement since different crops grow best at different pH levels. For most crops, optimum pH levels are between 6.0 and 7.0.

To correct acidic soil, farmers apply lime (dolomitic limestone is most typical) based on a pH and a soil test. An alkaline soil can be more difficult to correct since adding sulfur to make the soil more acidic is only a temporary remedy and can be more expensive than liming.

Organic matter acts as a significant buffer for pH, helping the soil to maintain a fairly constant and neutral pH and high CEC. CEC is highly dependent upon soil texture and organic matter content. In general, the more clay and organic matter in the soil, the higher the CEC. Sandy soils with very little organic matter (OM) have a low CEC. The disadvantages of a low CEC obviously include the limited availability of mineral nutrients to the plant and the soil's inefficient ability to hold applied nutrients. Plants can exhaust a fair amount of energy (that might otherwise have been used for growth, flowering, seed production or root development) scrounging the soil for mineral nutrients.

7) Crop Health and Vigor

Plant vigor is indicated by the health of individual plants in the field. The uniformity of growth shown by all crop plants in a particular field also suggests good plant vigor. With similar management, plants that emerge at about the same time should be ready for harvest about the same time. The plant is dependent on the root system to collect and transport nutrients and water essential to normal growth and development. Healthy plants often have root growth as extensive as above ground plant growth.

Good nutrition also promotes plant vigor. There are 16 plant nutrients or elements considered necessary for plant growth. Carbon, hydrogen, and oxygen make up most of the elements in plants and are used in the formation of organic compounds.

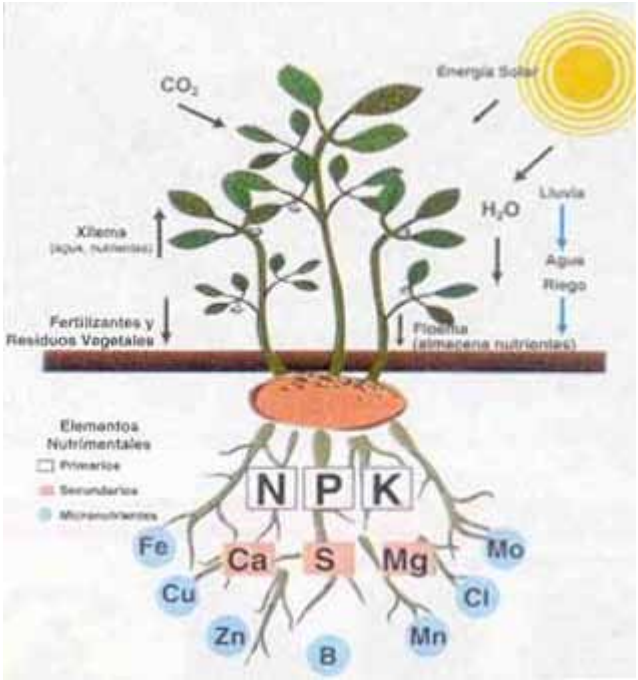


Figure 12. Sixteen Plant Nutrients Necessary for Plant Growth.

Macronutrients are those needed by plants in relatively large quantities, and the most important ones are nitrogen, phosphorus, and potassium.

Micronutrients are those needed by plants in relatively small quantities and include boron, copper, iron, chloride, manganese, molybdenum and zinc.

The other 13 elements are classified as **macronutrients** or **micronutrients** based on the amount found in plants. Nitrogen, phosphorus and potassium are the most important macronutrients. Other macronutrients include sulfur, calcium, and magnesium. Micronutrients include iron, zinc, manganese, copper, boron, chlorine, and molybdenum. If plants lack essential elements during their growth period, they will show signs of deficiency that will prevent healthy plant growth.

The following is an overview of the essential macronutrients and micronutrients for optimal plant growth:

Macronutrients

Nitrogen (N)

Nitrogen is an important macronutrient because it helps the plants grow, increases seed and fruit production and improves the quality of leaf and forage crops. The most common sources of N are from animal manure, either composted or raw, and green manures in the form of legumes that fix nitrogen from the atmosphere.

Additional sources of nitrogen include blood meal, fish emulsion, fish protein, kelp and seaweed, and various vegetable meals.

Macronutrients of greatest concern are:

Nitrogen (N) – helps plants grow, increased seed and fruit production, and improves the quality of leaf and forage crops.

Phosphorus (P) – Supports optimal plant growth, especially blooming and root growth

Potassium (K) – is necessary for photosynthesis, improves fruit quality and reduces disease

Nitrogen deficiency symptoms include the following:

- Stunted plants
- Older leaves or whole plants yellowish green
- Old leaves and sometimes all leaves become light green and chlorotic (yellow) at the tip
- Leaves die under severe N stress
- Except for young leaves, which are greener, leaves are narrow, short, erect, and lemon-yellowish green
- Entire field may appear yellowish
- Reduced tillering, small leaves, and short plants
- Reduced grain number

Phosphorus (P)

Phosphorus is an essential macronutrient nutrient for optimal plant growth, especially blooming and root growth. Sources of P include manure, bone meal, fish and poultry meal, and rock phosphate. Phosphorus deficiency symptoms include the following:

- Stunted plants
- Reduced tillering
- Leaves, particularly older ones, are narrow, short, very erect, and "dirty" dark green
- Stems are thin and spindly and plant development is retarded
- The number of leaves, panicles, and grains per panicle is also reduced
- Young leaves appear to be healthy but older leaves turn brown and die
- Red and purple colors may develop in leaves if the variety has a tendency to produce anthocyanin
- Leaves appear pale green when P and N deficiency occur simultaneously
- Mild to moderate P deficiency is difficult to recognize in the field
- P deficiency is often associated with other nutrient disorders such as iron toxicity t low pH, zinc deficiency, iron deficiency, and salinity in alkaline soils.

Other effects of P deficiency include:

- Delayed maturity (often by 1 week or more). When P deficiency is severe, plants may not flower at all.
- Large proportion of empty grains. When P deficiency is very severe, grain formation may not occur.
- Low 1,000-grain weight and poor grain quality.
- No response to mineral N fertilizer application.
- Low tolerance for cold water.
- Absence of algae in floodwater.
- Poor growth (small leaves, slow establishment) of green manure crops.

Potassium (K)

Potassium is an essential macronutrient nutrient for optimal plant growth because it is necessary for photosynthesis, improves fruit quality and reduces diseases. Sources of K include manure, alfalfa meal, kelp meal, greensand, wood ash, potassium sulfate, and granite dust.

Potassium deficiency symptoms include the following:

- Dark green plants with yellowish brown leaf margins or dark brown necrotic spots appearing first on the tip of older leaves
- Leaf tips yellowish brown under severe K deficiency
- Symptoms appear first on older leaves, then along the leaf edge, and finally on the leaf base
- Affected plants with upper leaves short, droopy, and "dirty" dark green
- Older leaves change from yellow to brown
- Discoloration gradually appears on younger leaves if deficiency is not corrected
- Leaf tips and margins may dry up
- Yellow stripes may appear along leaf interveins and lower leaves may bend downward
- Rusty brown spots on tips of older leaves and later spread over the whole leaf causing it to turn brown and dry if K deficiency is severe
- Irregular necrotic spots may also occur on panicles.
- Stunted plants with smaller leaves, short and thin stems
- Tillering is only reduced under very severe deficiency
- Greater incidence of lodging.
- Early leaf senescence, leaf wilting, and leaf rolling when temperature is high and humidity is low.
- Large percentage of sterile or unfilled spikelets caused by poor pollen viability
- Unhealthy root system (many black roots, reduced root length and density), causing a reduction in the uptake of other nutrients.
- Poor root oxidation power, causing decreased resistance to toxic substances produced under anaerobic soil conditions, e.g., iron toxicity caused by K deficiency.
- Increased incidence of diseases, particularly brown leaf spot (caused by *Helminthosporium oryzae*), cercospora leaf spot (caused by *Cercospora spp.*), bacterial leaf blight (caused by *Xanthomonas oryzae*), sheath blight (caused by *Rhizoctonia solani*), sheath rot (caused by *Sarocladium oryzae*), stem rot (caused by *Helminthosporium sigmoideum*), and blast (caused by *Pyricularia oryzae*) where excessive N fertilizer and insufficient K fertilizer have been used.

Sulfur (S)

This macronutrient is found in rainwater, especially in acid rain. Sulfur helps in chlorophyll formation, which gives a plant its green color. When a farmer uses organic sources of nitrogen, the sulfur requirements are usually met.

Calcium (Ca)

Calcium is an essential part of plant cell wall structure. It composes part of the cell wall structure and helps to transport and retain other elements. Calcium is a macronutrient generally supplied through lime applications used to adjust acidic soils. Sources include calcitic lime, and dolomitic lime that also contains magnesium. Other sources include colloidal phosphate, bone meal, gypsum, and wood ashes.

Magnesium (Mg)

Magnesium is part of the chlorophyll which greens plants and is essential for photosynthesis. It activates many plant enzymes necessary for plant growth. Sources include Dolomitic lime and langeinite.

Micronutrients

Chlorine, Copper, Manganese, Molybdenum, Nickel, and Zinc are micronutrients that are important for the proper development of many plant species. Micronutrients generally are important constituents of enzymes and thus critical for many plant functions, however these nutrients are found in plants at lower quantities in plants than nitrogen, phosphorus or other macronutrients.

Micronutrients are mostly satisfied through manure, compost, and liming amendments.

Plant nutrient deficiencies (Table 4)

Knowing nutrient plant deficiencies is the first step toward understanding deficiency symptoms in the field, and is an educational tool to be used in conjunction with soil testing and plant analysis. Environmental stress such as drought, wet conditions, disease, heat interactions can easily be misinterpreted as deficiency symptoms. Photographs of nutrient deficiencies are useful in diagnosis, but field experience and a knowledge of field history based on local experience is the best diagnostic aid. For more information visit the *Families of the Day* section for more information of nutrient deficiency symptoms.

Table 4. Generalized Symptoms of Plant Nutrient Deficiency or Excess. (Bennet, W.F., 1993)

Plant Nutrient	Type	Visual symptoms
Nitrogen	Deficiency	Light green to yellow appearance of leaves, especially older leaves; stunted growth; poor fruit development.
	Excess	Dark green foliage which may be susceptible to lodging, drought, disease and insect invasion. Fruit and seed crops may fail to yield.
Phosphorus	Deficiency	Leaves may develop purple coloration; stunted plant growth and delay in plant development.
	Excess	Excess phosphorus may cause micronutrient deficiencies, especially iron or zinc.
Potassium	Deficiency	Older leaves turn yellow initially around margins and die; irregular fruit development.
	Excess	Excess potassium may cause deficiencies in magnesium and possibly calcium.
Calcium	Deficiency	Reduced growth or death of growing tips; blossom-end rot of tomato; poor fruit development and appearance.
	Excess	Excess calcium may cause deficiency in either magnesium or potassium
Magnesium	Deficiency	Initial yellowing of older leaves between leaf veins spreading to younger leaves; poor fruit development and production.
	Excess	High concentration tolerated in plant; however, imbalance with calcium and potassium may reduce growth.
Sulfur	Deficiency	Initial yellowing of young leaves spreading to whole plant; similar symptoms to nitrogen deficiency but occurs on new growth.
	Excess	Excess of sulfur may cause premature dropping of leaves.
Iron	Deficiency	Initial distinct yellow or white areas between veins of young leaves leading to spots of dead leaf tissue.
	Excess	Possible bronzing of leaves with tiny brown spots.
Manganese	Deficiency	Interveinal yellowing or mottling of young leaves.
	Excess	Older leaves have brown spots surrounded by a chlorotic circle or zone.
Zinc	Deficiency	Interveinal yellowing on young leaves; reduced leaf size.
	Excess	Excess zinc may cause iron deficiency in some plants.
Boron	Deficiency	Death of growing points and deformation of leaves with areas of discoloration.
	Excess	Leaf tips become yellow followed by necrosis. Leaves get a scorched appearance and later fall off.

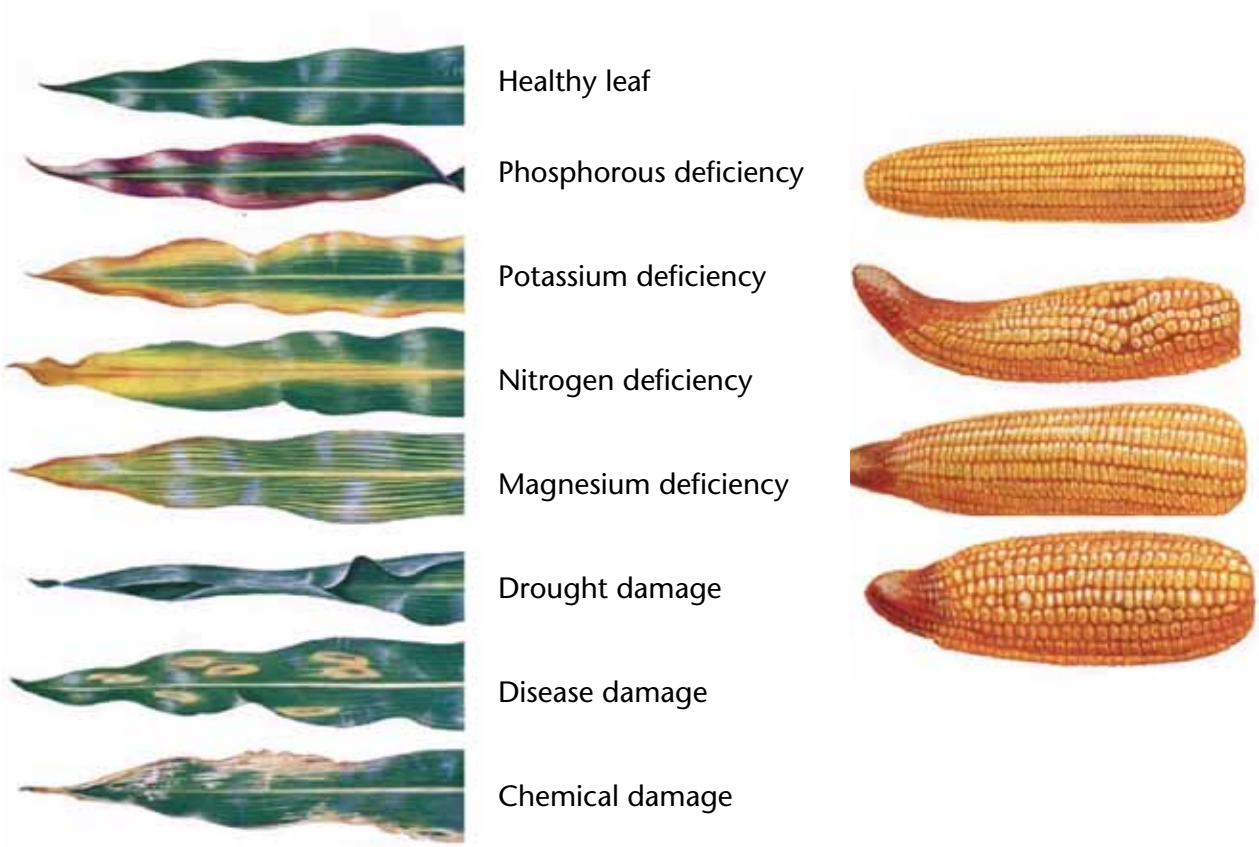


Figure 13. Identify deficiencies by leaf appearance

The Nitrogen Cycles→Nitrogen in the Soil
The circulation of nitrogen in nature consists of a cycle of chemical reactions in which atmospheric nitrogen is compounded, dissolved in rain, and deposited in the soil, where it is assimilated and metabolized by bacteria and plants, eventually returning to the atmosphere by bacterial decomposition of organic matter.

The growth of all organisms depends on the availability of mineral nutrients, and none is more important than nitrogen. There is an abundant supply of nitrogen in the earth's atmosphere —nearly 79% in the form of N_2 gas. However, N_2 is unavailable for use by most organisms. Therefore, in order for nitrogen to be used for growth it must be "fixed" in the soil or the air (combined) in the form of ammonium (NH_4) or nitrate (NO_3) ions through **nitrogen fixation, decay, nitrification, and denitrification,** all part of the Nitrogen Cycle.

Even though there is an abundant supply of nitrogen gas in the earth's, it must be converted from the gas to a form that plants can use. This is called the **Nitrogen Cycle.**

The Nitrogen Cycle requires these processes to convert from gas to a useable form

Nitrogen fixation
Decay
Nitrification

Dentrification is the last part of the Nitrogen Cycle that converts the usable form of Nitrogen back to gas to be released in the atmosphere.

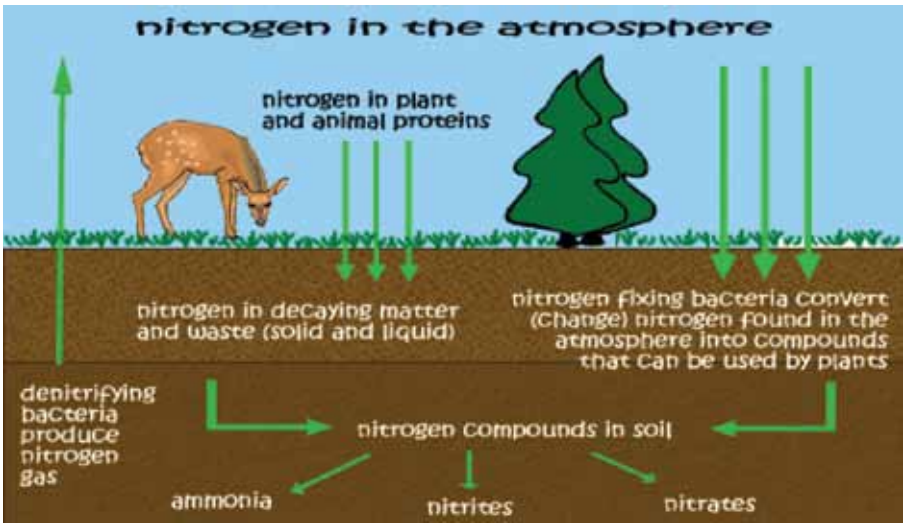


Figure 14. Nitrogen Cycle.

Understanding the how nitrogen is fixed through the 4 parts of the nitrogen cycle is important in soil fertility management and crop production: **Nitrogen fixation, decay,** and **nitrification** remove nitrogen from the air and pass it to the ecosystems on the ground. **Denitrification** does just the opposite: it takes the nitrate form and converts them to gas, which is released back into the atmosphere. Each process of the nitrogen cycle is described below:

1. ***Nitrogen fixation*** is one process by which molecular nitrogen is reduced to form ammonia. This complex process is carried out by nitrogen-fixing bacteria present in the soil. Symbiotic nitrogen fixation occurs in plants that harbor nitrogen-fixing bacteria within their tissues.

The best-studied example is the association between **legumes** and **Rhizobia** bacteria. Legumes and Rhizobia are able to survive independently, but when they live together, life is clearly beneficial to both. Only together can nitrogen fixation take place.

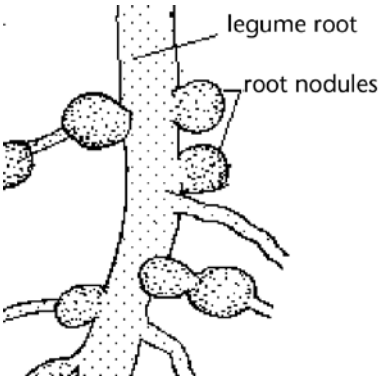


Figure 15. Legume Roots

There are many types of Rhizobia bacteria that live freely in the soil (especially where legumes have been grown). However, they cannot fix atmospheric nitrogen until they have invaded the roots of the appropriate legume. Once the Rhizobia invades the root system of the "appropriate" legume, a node with nitrogen fixing receptors is secreted by the rhizobia on the cells of the root hairs of the legume. Different strains of rhizobia produce different types of node receptors, and different legumes produce receptors of different specificity. The development of nodules, while dependent of rhizobia, is a well-coordinated developmental process of the plant.

Inside the node is all the necessary metabolic machinery — including the enzyme **nitrogenase** — needed to fix nitrogen.

Not all nitrogen fixing bacteria will infect the same kind of legume. Some rhizobia only infect peas, some only clover, some only alfalfa, etc. Treating legume seeds with the proper strain of rhizobia is a routine agricultural practice. (The Nitragin Company specializes in producing rhizobial strains appropriate to each leguminous crop.)

Rhizobia bacteria trap nitrogen from the atmosphere in the nodules of the legume roots.

Some bacteria convert the nitrogen from the atmosphere into nitrates, nitrites and ammonia, which can be used by the plants

Other bacteria convert nitrates back to nitrogen gas, which goes back to the atmosphere.

2. ***Decay*** – When plants die their proteins metabolize to produces organic nitrogen compounds that return to the environment. The final beneficiaries of these materials are microorganisms of decay. They break down the molecules in excretions and dead organisms into **ammonia**.
3. ***Nitrification*** – Ammonia can be taken up directly by plants — usually through their roots. However, most of the ammonia produced by decay is converted into **nitrates.** This is accomplished by **Nitrosomonas** and **Nitrobacter** bacteria, that through their activities, make nitrogen available to the roots of plants

Many legumes, in addition to fixing atmospheric nitrogen, also perform nitrification — converting some of their organic nitrogen to nitrites and nitrates. These reach the soil when they shed their leaves.

4. ***Denitrification*** reduces nitrates to nitrogen gas, thus replenishing the atmosphere. Once again, bacteria are the agents. They live deep in soil and in aquatic sediments where conditions are anaerobic. They use nitrates as an alternative to oxygen for the final electron acceptor in their respiration.

Nutrient Budgeting

A nutrient budget is the comparison between all the sources of nutrients available to the producer and the requirement of nutrients to meet the crop and soil needs. They're useful tools to plan ahead and keep track of what's coming in and going out.

A nutrient budget allows you to identify nutrient inputs on the farm, such as:

Commercial Fertilizer and/or Compost

Nitrogen (N) and phosphorus (P) in commercial fertilizer for different crops, pastures, lawns, etc.

Manure

N and P in livestock waste, like beef, hogs, sheep and poultry

Atmospheric deposition

N and P dissolved in precipitation, attached to windblown particles or as aerosols

Legume fixation

Atmospheric N "fixed" by symbiotic bacteria for soybean, alfalfa and other legume crops

Industrial waste

N and P discharged from industrial plants

Creating a nutrient budget also allows you to identify where nutrients go off the farm, such as:

Harvest

N and P in crops that are consumed by grazing animals and harvested as grain

Fertilizer and manure volatilization

When nutrients are converted to gas and passed off into the atmosphere. Nitrogen coverts to vapor and is lost to the atmosphere, primarily as ammonia

Volatilize —to pass of as vapor or gas

Crop volatilization

N that volatilize from growing and withering crops, mainly as ammonia

Stream loads

N and P that ends up in streams and rivers, calculated using stream N and P concentrations and flow rates for 1999-2001

Denitrification

N nitrates converted to nitrogen gas by anaerobic bacteria and lost to the atmosphere as nitrogen gas

The last line on your nutrient budget tells you the balance between nutrient inputs and outputs to determine whether nutrients are used efficiently or to indicate the amount of avoidable nutrient leaching and runoff. Nutrients lost to waterways cause reduce water quality.

Recommended Management

For optimal plant health and vigor management decisions will need to incorporate organic matter that provides the essential nutrients needed for optimal plant growth. It is critical to know what nutrients are deficient in the soil.

Management Decisions that can be employed to provide necessary nutrients to the soil:

- **Composting**
- **Crop Rotations**
- **Animal and Green Manures**
- **Cover Cropping**

The crop should be examined for pest or disease damage. It is important to determine if the disease problem is related to soil quality. For example, root-borne diseases may be in part caused by poor soil quality in the form of compacted soil that remains saturated over long periods. Management practices that encourage good soil structure and a proper balance of nitrogen fixing reactions will help promote healthy root and plant growth. A fertile soil also provides the essential nutrients to a growing crop plant and helps support a diverse and active biotic community.

Management decisions the transitional farmer will employ to build the soil quality are: Composting, Crop Rotations, Animal and Green Manures, and Cover Cropping:

On-Farm Composting is the decomposition of plant remains and other once-living materials to make an earthy, dark, crumbly substance to add to the soil. Compost provides many important minerals and nutrients to plants and can improve soil structure.

Figure 16. Compost Pile

It is a good idea to compost manure, because the heat created during composting may kill weed seeds and break down contaminants such as antibiotics. Fresh manure generally will have higher available nitrogen, but over applications can lead to salt buildup and **leaching**. A soil test to monitor soil fertility is highly recommended so the farmer can add the right amount of raw or composted manure to plots and avoid nutrient imbalances.

Leaching is the loss of nutrients caused by the draining of water through the soil.

Cover cropping can be an annual, biennial, or perennial herbaceous plant grown in a pure or mixed stand for all or part of the year. This crop provides soil cover and can help loosen compacted soil through the growth of roots and improved water filtration. Cover crops can maintain or increase soil organic matter if they are allowed to grow long enough to produce high herbage.

Cover crops also help prevent soil erosion caused by both water and wind, suppress weeds by keeping the sun from reaching weed seeds, and reduce insect pests and diseases. In addition, a legume used as a cover crop can provide nitrogen to the soil. Non-legumes can take up excess nitrogen, phosphorus, and potassium from previous crops and recycle them to the following crop.

Common cover crops and green manures include:
rye, buckwheat, hairy vetch, crimson clover, subterranean clover, red clover, sweet clover, cowpeas, millet, and forage sorghums.

Green manures
When a cover crop is tilled into the soil while it is still lush and green, it is referred to as a green manure. Green manures are important under an organic farming system because they help to add organic matter and nutrition to the soil. When a green plant is incorporated into the soil, it has high amounts of nitrogen and moisture and becomes a food source for soil microorganisms and earthworms.

Organisms in the soil decompose organic matter, and nutrients become available to the crop plants. An additional benefit of using green manures is the suppression of weeds and soilborne diseases. For more information, read "Overview of cover crops and green manures" at **(www.attra.ncat.org/attra-pub/)**.

Animal manures have traditionally been used to fertilize soils of both organic and sustainable farms. Manure can be applied to the field in either raw or composted form. The organic farmer must follow the Final Rule's specific requirements for using raw or composted manure.

Final Rule Requirements

The EPA mandates that large animal feeding operations develop and implement a comprehensive nutrient management plan for their operations to ensure that manure and wastewater are properly managed. Medium and small animal feeding operations are asked to partake in this initiative.

This Legislation intends to alleviate runoff of manure and manure nutrients to promote better farm management and higher water quality.

To learn more:
http://www.sec.nv.gov/cafo/tab_d.pdf

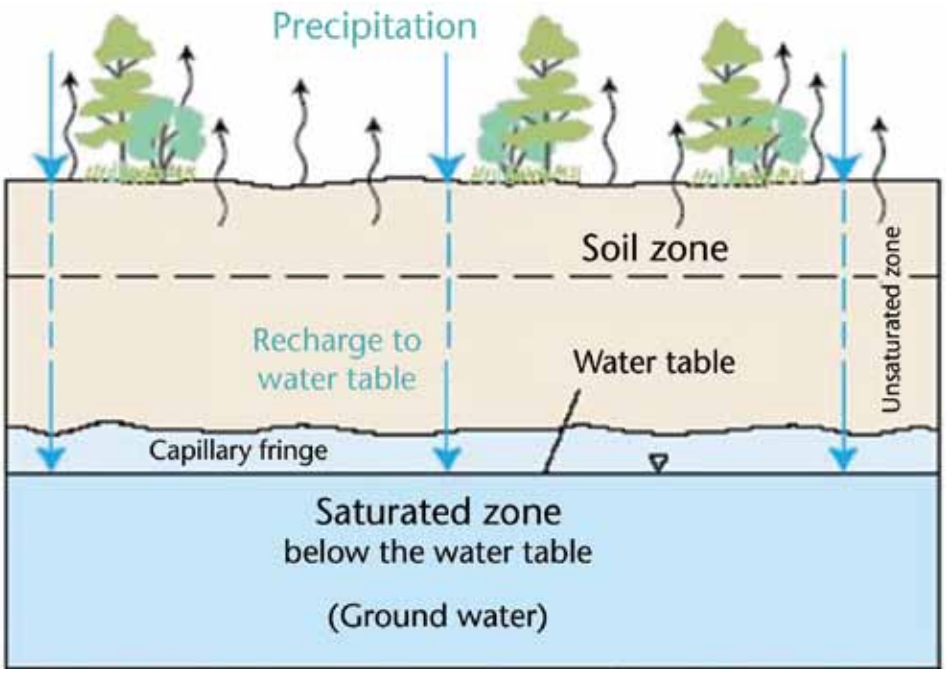
Raw manure is useful in supplying nutrients and adding organic matter to the soil, as well as encouraging healthy biological processes in the soil.

However, it is important to know what is in the manure because some may contain contaminants, and nutrient content varies with the animal, bedding, and storage

Crop rotations
Many farmers find that rotating crops improves the tilth or aggregation of the soil. Planning a crop rotation requires a farmer to plant crops at different times and in different locations in the same field. Usually, the succeeding crop will be of a different variety and species than the previous crops. Crop rotations can also be used to promote the soil's fertility, reduce erosion, reduce the buildup of pests, and spread out financial risk in case a crop fails. Farmers who include a legume in the rotation can increase the availability of nitrogen in the soil. The rhizobia that form on the nodules of legume roots convert nitrogen from the atmosphere into organic nitrogen, which that then becomes available to plants.

8) Water Infiltration

Water Infiltration is the process of downward water movement into the soil under saturated conditions such as occurs after a heavy rain. Soil tilth is one important factor that controls water infiltration because the tilth determine the porosity of the soil. The number, lengths, and diameters of pores determine water movement and retention in soils. Large pores (greater than 1/16th inch in diameter) are responsible for most of the flow through soils. Sandy soils in general will have higher infiltration rates than silty or clay soils. The slope of the land also determines the rate of water movement into the soil. Water tends to drain more quickly from positions higher on the landscape.



As water infiltrates down into the soil, it arrives at the water table.

The infiltrated water recharges the ground water to ensure lasting supplies.

Figure 17. Water infiltration through the soil-water unsaturated zone and into the water table
(http://dhn.iihr.uiowa.edu/runoff/showMan.php?c1=2E-1)

Natural and Artificial Causes of Water Infiltration

Water infiltration can be induced naturally by precipitation or artificially by the building of dams and other structural modifications to the land surface.

Flooding is the temporary covering of the soil surface by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources.

Ponding is the temporary flooding of soil surfaces. Ponding can affect a very small area when a puddle is present or a large area when small to mid-size ponds are created.

Permeability is the quality of the soil that enables water or air to move through it. Soil properties such as texture, structure, pore size, pore shape and density are used to predict permeability. Historically, soil surveys have used permeability as a term for saturated hydraulic conductivity. Permeability rates are used to predict soil suitability for irrigation and drainage systems, septic tank absorption fields, and terraces and other conservation practices.

Soil and Water Run-off. Soils with good infiltration will have less surface runoff and be more resistant to erosion. Good water infiltration means the soil will dry out and warm up more quickly after heavy rains. Other factors that influence soil and water run-off include: thickness of soil, depth to seasonal water table, rock and gravel content, depth to slowly permeable layer, and soil texture.

Runoff occurs when precipitation from rain or snow is not absorbed in the soil and flows over the land. **Figure 14** illustrates this phenomenon.

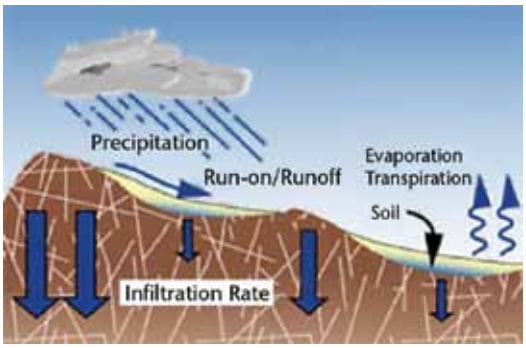


Figure 18: Soil and Water Runoff

Increased run off contributes to poor water quality for various reasons:

1. Carries away nutrients that are needed for good soil ph and quality
2. Carries layers of topsoil away from farm fields and into nearby water sources

Basic Test: Water Infiltration

Materials needed: Notebook
Observe the field after a saturating rain or irrigation, and record how long water stands in the field.

Rating this indicator: 0-10

0 = least desirable. There is ponding on the soil for more than 3 days after rainfall or irrigation has ended.

5 = Moderate. Ponding lasts up to 3 days after rainfall and irrigation has ended.

10 = Preferred. No ponding is seen on the soil 24 hours after rainfall and irrigation has ended.

Recommended Management

Management that promotes top soil with a loose granular or crumb structure composed of aggregates that maintain their integrity when wet will be conducive to good water infiltration. Tillage operations that preserve soil structure will promote good water infiltration rates. Partial incorporation or addition of residues or cover crops improves infiltration, as coarsely fibrous material can help provide channels for water movement through the soil. Surface residue cover is also important in promoting high infiltration rates and preventing crusting.

9) Soil Water Holding Capacity

Soil water capacity is the ability of soil to hold enough water to allow normal development of crops throughout the production season. Water held in soil pores that the plant roots can use is called available water. Due to suction forces within soil pores this water resists evaporation and percolation, but is not so strongly held that roots cannot absorb it.

Available Water Capacity (AWC) is the volume of water that should be available to plants if the soil were at field capacity. Farmers must estimate the amount of water held between field capacity and wilting point (the point at which the plant will die).

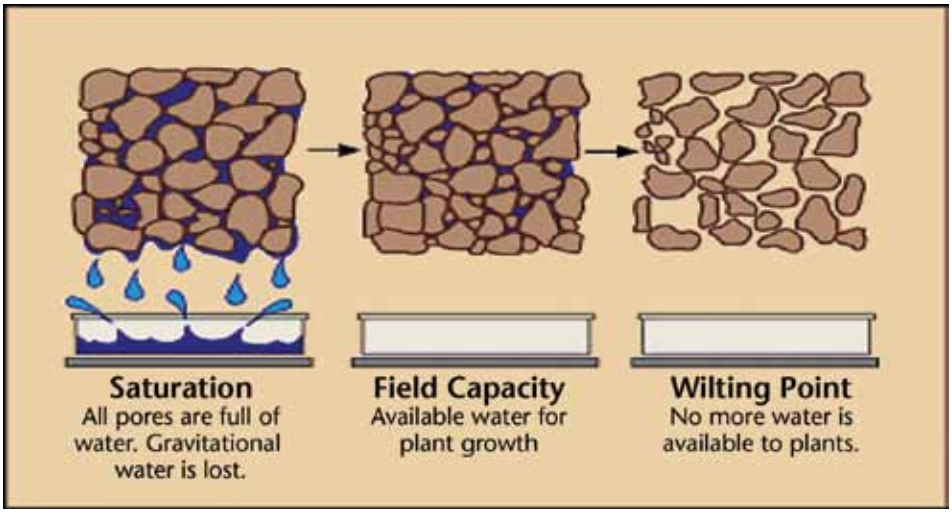


Figure 19. Water Holding Capacity

www.bettersoils.com.au/module2/2_1.htm

Adequate water storage in the soil reduces operation costs related to stand establishment, normal plant development, nutrient leaching associated with erosion, and irrigation operations.

Basic Test: Soil Water Holding Capacity

Record the amount of time between irrigations for the crop or how long after a soaking rain the crop begins to show signs of water stress. Be sure to record weather observations, because evaporation from the soil also is a factor and plants transpire more moisture on sunny days.

Rate your Indicator: 0-10

0 = Least desirable. The soil does not hold water for plant growth; frequent extra irrigation is necessary.

5 = Moderate. The soil has water available for some time after irrigation or rain.

10 = Preferred. The soil provides enough water to crops for an adequate period of time between rains or irrigations.

Recommended Management

Water holding capacity is largely determined by soil texture, but can be enhanced by increasing soil organic matter content. Practices that reduce compaction and lower bulk density such as organic matter additions and not traveling over fields when they are wet will improve water availability in soils. Management that improves aggregate stability and the number of fine aggregates will increase infiltration, giving the water more soil to hold, as well as increasing the amount of readily available water held.

10) Soil Erosion

Erosion is defined as the movement of topsoil and nutrients from production areas to sites where they are not wanted. Erosion is a serious threat to water quality; sediment is the primary cause of water pollution and nutrient runoff. Soil erosion is detrimental to farmers as it leads to a loss of the most productive part of the soil.

Natural Erosion is the relatively slow sculpturing of landscapes by climatic factors over geologic time.

Accelerated Erosion is the rapid alteration of landscapes due to land disturbing

Activities such as urbanization, tillage, grazing, or timber cutting etc. These activities increase erosion rates by exposing the soil surface to wind and rain fall.

Remember: when water cannot infiltrate down to the water table, it causes run off that carries topsoil and water.

This runoff is one example of erosion.

Recommended Management

To keep soil from eroding, farmers employ the following practices:

Conservation Cover provides guidelines for establishing and maintaining perennial vegetative cover on land retired from agricultural production. Covers help reduce soil erosion and sedimentation, improve water quality, and create or enhance wild life habitat.

Cover and Green Manure Crop provides guidelines for establishment of a crop of close growing, legumes, or small grain. Cover crops provide seasonal protection and add organic material to the soil to improve infiltration, aeration and tilth.

Conservation Crop Rotation provides guidelines on growing crops in a recurring sequence on the same field. This practice can maintain and improve soil organic matter content, manage deficient or excess plant nutrients, improve water use efficiency, manage plant pests (weeds, insects and diseases) and reduce sheet and rill erosion by water and wind erosion.

Residue Management provides guidelines for managing amount, orientation, and distribution of crop and other plant residue on the soil surface year-round, while growing crops under Mulch Till, No-Till, Reduced -Till, Strip-Till, or Ridge-Till management systems. Improved residue management can reduce sheet and rill erosion and soil erosion by wind, maintain or improve soil organic matter content and tilth and conserve soil moisture.

Contour Buffer Strips provides guidelines for establishment of narrow strips of perennial, herbaceous cover across slopes and alternated down slopes with wider cropped strips. Buffer strips can help reduce sheet and rill erosion, reduce transport of sediment and other water-borne contaminants down slope, on-site or off-site, and enhance wildlife habitat.

Contour Farming provides guidelines for farming sloping land in such a way that preparing land, planting, and cultivating are done on the contours. This practice can reduce sheet and rill erosion and control water.

Field Border provides guidelines for establishment of a strip of perennial vegetation at the edge of a field. This practice helps protect edges of fields that are used as "turn rows" or travel lanes for farm machinery. It can also help reduce travel over cultivated areas that are subject to compaction.

Conservation Tillage—Managing crop residues and preparing seedbeds for planting through tillage can damage the soil structure and lead to an increase in erosion and the loss of organic matter. Tillage will smooth the soil surface while incorporating plant residue. In the process, it destroys the soil structure as well as earthworm channels. When the soil structure is damaged, there is a decrease in pore space, which means a decrease in air and water infiltration. Many farmers are switching to conservation tillage methods to manage crop residue and prepare seedbeds by preserving the residue from the previous crop and reducing the number of times equipment passes over a field. For more information about conservation tillage, refer to the Appropriate Technology Transfer for Rural Areas (ATTRA) publication "Pursuing conservation tillage systems for organic crop production" **(www.attra.ncat.org/attra-pub/)**.

Soil Test and Evaluation

The soil test is an excellent measure to test for optimal soil fertility. It is a very inexpensive way of maintaining good plant health and maximum crop productivity. Using soil tests and monitoring crop growth will indicate to the farmer what nutrients need to be added to the soil. The soil test is often required for organic certification.

The standard soil test provides the status of phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), pH, cation exchange capacity, lime requirement index, and base saturation. Additional tests are also available for iron (Fe), zinc (Zn), manganese (Mn), soluble salts, and nitrates.

How Do I Take Soil Sample for a Soil Test?

- Sample when soils are suitable for spading or plowing. A soil test sample is best taken with a soil probe or an auger.
- Soils should be collected in a clean plastic bucket, paper bags or box
- Take10–15 samples from different places in the garden
- Sample 6–8 inches deep. Each sample should be taken at the same depth and volume at each site.
- Sample at random in a zigzag pattern over the area and mix the sample together in a clean plastic bucket
- Sample between rows to avoid fertilizer bands.
- Take separate samples from soils that are distinguishable by color (i.e. light vs. dark), drainage, or other factors.
- Submit a composite sample to the testing lab.

How to Prepare Soil Samples for Submission

1. Contact a soil testing lab for instructions, soil test kits, and appropriate forms.
2. Break up lumps and air dry the soil at room temperature with no artificial heat.
3. When the soil is dry, mix well and crush soil lumps to the size of wheat grains or smaller.
4. Take about one pint of the composite sample and place it in the sample bag associated with the kit.

Where can I have a soil test done?

You need to mail soil sample(s), completed sample form(s), and appropriate payment to the soil testing lab you selected. Generally, soil testing labs will provide a complete set of instructions, either with sample kits or upon request. Follow the instructions carefully.

How Long Does the Soil Test Take?

Soil test results and fertilizer recommendations are usually mailed in two weeks, depending on the labs you work with. Make sure you fill out the form for the types of plants you grow or will be growing. Otherwise, no recommendations will be given. Indicate whether the crop is planted, or is to be planted. Incomplete forms may cause delays in receiving results and recommendations.

There are several commercial labs that offer soil tests in our area:

Laboratory	Phone Number	Address	Services
Perry Laboratory	408/722-7606	471 Airport Blvd. Watsonville, CA 95076	horticultural advising & testing
Plant Disease Diagnosis (Louellen Pierce)	510/937-3841	780 Palmer Rd. Walnut Creek, CA 94596	turf grass and plant disease diagnostics
Primus Group, Inc.	805/922-0055	3130 Skyway Dr. Ste.308 Santa Maria, CA 93455	pesticide residues, microbes, plant tissues, soil and water

Compiled by Marcella E. Grebus, Ph.D., Plant Pathology Specialist, UC Riverside

Table 5. Local Commercial Labs for Soil Tests. (Grebus)

Conclusion

"Feed the soil and it will feed the crops." *~Robert Rodale*

While there are many indicators of soil conditions, there are several key steps you can take and actions you should avoid that will benefit many of these indicators both now and over the longer term.

1. **Incorporate organic material—such as compost or residues from previous crops—into the soil.**
   You can increase organic matter in soil by adding compost, manure or disking in cover crops, or "green manures." Organic matter provides food for earthworms and microscopic organisms that decompose dead plant material. Some of the decomposition products glue soil particles into aggregates, and therefore improve soil structure, water infiltration and aeration. They also provide nitrogen, sulfur and phosphorous for crops. Organic matter also helps soil to retain more nutrients by increasing its cationic-exchange capacity. Farmers associate the dark soil color from organic matter with thickness of plow layer, water storage, drought tolerance, seed bed workability and the availability of plant

   Incorporating cover crops and other organic residues helps build soil organic matter and is important in counteracting compaction. Earthworms can eat through compacted layers if the soil is wet, primarily in clay and silty soils. Further, surface plant residues protect soil from the erosive impact of rain. When organic residue is distributed through the topsoil, it slows the flow of surface water into the soil and reduces erosion by water runoff.

2. **Plant a cover crop for all or part of the year.**
   Leaving a field bare, or fallow, over the winter can result in erosion, as many of the most productive parts of the soil are blown away by the wind or swept away by water. The cover crop provides soil cover to present erosion. Further, if cover crops are allowed to grow long enough to produce high herbage, they can contribute organic matter to the soil. Some cover crops have extensive root systems that can help loosen compacted soil and improve water filtration and aeration. Legumes, a type of cover crop, fixes nitrogen in the soil so that it can be utilized by the plants. Non-legumes can take up excess nitrogen, phosphorus, and potassium from previous crops and recycle them to the following crop. Common cover crops and green manures include rye, buckwheat, hairy vetch, crimson clover, subterranean clover, red clover, sweet clover, cowpeas, millet, and forage sorghums.

3. **Rotate the crops that are grown on the same soil at different times of the year.**
   Many farmers find that rotating crops improves the soil tilth. Planning a crop rotation requires a farmer to plant crops at different times and in different locations in the same field. Usually, the succeeding crop will be of a different variety and species than the previous crops. Crop rotations can also be used to promote the soil's fertility, reduce erosion, reduce the buildup of pests, and spread out financial risk in case a crop fails. Farmers who include a legume in the rotation can increase the availability of nitrogen in the soil.

4. **Avoid compacting the soil by reducing tillage and not working the soil when wet.** Compaction occurs when farm machinery passes over the same area of soil repeatedly, or, it can occur from only one pass, if it is made when the soil is wet. The degree of compaction increases with the weight of the equipment and the number of trips across the field. The weight of the equipment, the number of trips across the field, and the type of soil determine the degree of compaction. The more intensely the soil is tilled, the more likely it is to be compacted.

   Compaction that restricts crop roots to the upper few inches of soil layers increases production costs by increasing runoff, erosion, seedling mortality and susceptibility to crop damage during periods of drought. Compaction can be limited by not working the ground or avoiding heavy grain trucks and manure spreaders when the soil is too wet. The sliding action of tillage equipment over the same layer of sub-soil can also create impenetrable compaction just below the tilling zone. Physically breaking through a deep compacted layer with sub-soiling equipment can help counteract deep compaction. Deep chiseling (ripping) can alleviate some compaction problems, but in some cases only for the short term.

5. **Test the key indicators of soil fertility regularly so that you know what the soil needs** The above recommendations provide general guidelines for maintaining productive, healthy and sustainable. Whether you want to improve soil structure, increase nutrient availability, or prevent erosion, testing the key soil indicators can help determine what actions will most benefit the soil and particular crops.

   For instance, a soil nutrient test is necessary so the farmer can add the right amount of raw or composted manure or liming amendments to plots and avoid nutrient imbalances. It is critical to know what nutrients are deficient, or excessive, in the soil in order to determine. However, the crop should be examined for pest or disease damage as well. Disease problems may even be related to soil quality. For example, root-borne diseases may be more prevalent in compacted soil that remains saturated over long periods. Further, knowing the pH of your soil will help you determine what crops will thrive and which will require making the soil more acidic or alkaline.

Create a Soil Fertility Plan

Answer the following questions to determine for your 0.5 acre:

1) How will you build good Soil Tilth? (RDC is typically sandy loam type soil)

2) How will you avoid Soil Compaction?

3) Is your Soil Workable? If so, how will you prepare your beds?

4) Do you have Biodiversity in your soil? How do you know?

5) How will you build Organic Matter?

6) What specific nitrogen sources will you incorporate in your field?

7) What is your Soil pH? How can you find out?

8) What is the Water Holding capacity of your soil? How do you know?

9) Does your soil have adequate Water Infiltration? How do you know?

10) How will you avoid Soil Erosion during the season?

11) Do you believe your soil will support good Crop Health and Vigor? Why?

Resources

1. Adapted from: W.F. Bennett (editor), 1993. Nutrient Deficiencies & Toxicities in Crop Plants, APS Press, St. Paul, Minnesota.

Animal manure—**http://www.wvu.edu/~agexten/farmman2/organic/convert.pdf**

Figure 14. Water infiltration through the soil-water unsaturated zone and into the water table **(http://dhn.iihr.uiowa.edu/runoff/showMan.php?c1=2E-1)**

National Organic Program. 2008. United States Department of Agriculture. 13 Nov. 2008. <**http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateA&navID=NationalOrganicProgram&leftNav=NationalOrganicProgram&page=NOPNationalOrganicProgramHome&acct=nop**>

For a complete list of prohibited and allowed substances, go to the USDA's National Organic Program's Web site **(http://www.ams.usda.gov/nop/NationalList/FinalRule.html)**.
(Maintaining Soil Fertility Under an Organic Management System By Melissa Van Tine, 2003
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Sullivan, P. (2003). "Overview of Cover Crops and Green Manures." National Sustainable Agriculture Information Service. 13 Nov. 2008. < **http://attra.ncat.org/publication.html**>
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Pimental, D., et al. 1995 Environmental and economic costs of soil erosion and conservation benefits. Science. Vol. 267, No. 24. p. 1117–1122

www.bettersoils.com.au/module2/2_1.htm - The image used on page 18 no longer exists but **www.bettersoils.com** is Wallace laboratories pg. 18

water infiltration to groundtable graphic h**ttp://dhn.iihr.uiowa.edu/runoff/showMan.php?c1=2E-1**

Farmers;choice

http://www.sec.nv.gov/cafo/tab_d.pdf
24-26 nitrogen cycle graphics
pg 28 compost photo

plant nutrients

Figure ####/ Sixteen Plant Nutrients Necessary for Plant Growth.

Table #: Appropriate pH Levels of Common Crops.

Siol biodiversity picture

http://soils.usda.gov/sqi/concepts/soil_biology/sbclipart.html

all intoduction and soil tilth photos.

Compiled by Marcella E. Grebus, Ph.D., Plant Pathology Specialist, UC Riverside

Table 5. Local Commercial Labs for Soil Tests. (Grebus, #####)

Soil erosion is detrimental to farmers as it leads to a loss of the most productive part of the soil in the Waikito Region

Glossary of Terms

Acidic soil – The pH scale is a measure of balance between acidity and alkalinity of soil solutions. A neutral soil solution has pH 7 while an acidic soil solution has pH less than 7 (more H^+ than OH^-)

Alkaline soil – The pH scale is a measure of balance between acidity and alkalinity of soil solutions. A neutral soil solution has pH 7 while an alkaline soil solution has pH more than 7 (more OH^- than H^+)

Anion – a negatively charged ion (NO_3^-, PO_4^{2-}, SO_4^{2-}, etc...)

Cation – a positively charged ion (NH_4^+, K^+, Ca^{2+}, Fe^{2+}, etc...)

Composting – Composting is the decaying of organic matter (food, leafy, woody material or manure), producing compost.

Conservation Cover – provides guidelines for establishing and maintaining perennial vegetative cover on land retired from agricultural production. Covers help reduce soil erosion and sedimentation, improve water quality, and create or enhance wild life habitat.

Conservation Crop Rotation – provides guidelines on growing crops in a recurring sequence on the same field. This practice can maintain and improve soil organic matter content, manage deficient or excess plant nutrients, improve water use efficiency, manage plant pests (weeds, insects and diseases) and reduce sheet and rill erosion by water and wind erosion.

Conservation Tillage – Management of crop residue and prepare seedbeds by preserving the residue from the previous crop and reducing the number of times equipment passes over a field.

Contour Buffer Strips – Establishment of narrow strips of perennial and herbaceous plants across slopes and along alternated down slopes with wider cropped strips. Buffer strips can help reduce sheet and rill erosion, reduce transport of sediment and other water-borne contaminants down slope, on-site or off-site, and enhance wildlife habitat.

Contour Farming – Farming sloping land in such a way that preparing land, planting, and cultivating are done on the contours. This practice can reduce sheet and rill erosion and control water.

Cover and Green Manure Crop – provides guidelines for establishment of a crop of close growing, legumes, or small grain. Cover crops provide seasonal protection and add organic material to the soil to improve infiltration, aeration and tilth.

Cover crop – A cover crop is any annual, biennial, or perennial plant grown as a monoculture (one crop type grown together) or polyculture (multiple crop types grown together), to improve and manage soil fertility, soil quality, water, weeds, pests, diseases, and wildlife.

Crop Health and Vigor – A soil indicator that measures a number of crop health and vigor components such as crop uniformity, plant height, extensive root system, and higher nutrient content.

Crop rotation – The practice of growing a series of different types of crops in the same space in sequential seasons for various benefits such as to avoid the build up of pathogens and pests that often occur when one species is continuously cropped. Crop rotation also seeks to balance the fertility demands of various crops to avoid excessive depletion of soil nutrients. A traditional component of crop rotation is the replenishment of nitrogen through the use and incorporation of green manures or cover crops. Crop rotation can also improve soil structure and fertility by alternating deep-rooted and shallow-rooted plants.

Denitrification – The conversion of nitrate to nitrogen gas. Denitrification is a natural process carried out by many microorganisms when sufficient oxygen is lacking.

Field Border – Establishment of a strip of perennial vegetation at the edge of a field. This practice helps protect edges of fields that are used as "turn rows" or travel lanes for farm machinery. It can also help reduce travel over cultivated areas that are subject to compaction.

Flooding – A temporary covering of the soil surface by flowing water from any source, such as streams overflowing their banks, runoff from adjacent or surrounding slopes, inflow from high tides, or any combination of sources.

Green manures – When a cover crop is tilled into the soil while it is still lush and green, it is referred to as a green manure

Nitrification – The process by which ammonia is converted to nitrites (NO2-) and then nitrates (NO3-). This process naturally occurs in the environment, where it is carried out by specialized bacteria; nitrosomonas and nitrobacters.

Nitrogen cycle – A biogeochemical cycle that describes the transformations of nitrogen and nitrogen-containing compounds in nature.

Nitrogen fixation – is the process by which nitrogen is taken from its natural, relatively inert molecular form (N_2) in the atmosphere and converted into nitrogen compounds (such as ammonia, nitrate and nitrogen dioxide).[1]

Nutrient Budgeting – The process involves balancing nutrients coming into the farming system with those leaving. The aim is to prevent pollution events and save costs by precisely matching the nutrient requirements of the crop with application of organic fertilizers.

Permeability – is the quality of the soil that enables water or air to move through it. Soil properties such as texture, structure, pore size, pore shape and density are used to predict permeability.

Ponding – The temporary flooding of the soil surface in the field such as small to mid size pond and puddle.

Residue Management – The process of managing the amount, orientation, and distribution of crop and other plant residue on the soil surface. Improved residue management can reduce sheet and rill erosion and soil erosion by wind, maintain or improve soil organic matter content and tilth and conserve soil moisture.

Soil and Water Run-off – A process of soil erosion when there is a lack of the following: good water infiltration, thickness of soil, depth to seasonal water table, rock and gravel content, depth to slowly permeable layer, and soil texture.

Soil Biodiversity – A soil indicator that measures the variety of organisms and biological activity within the soil.

Soil Compaction – A soil indicator that is influenced by weight on the soil from such things as livestock or heavy machinery which compresses soil, causing it to lose pore space. Affected soils become less able to absorb rainfall, thus increasing runoff and erosion.

Soil Erosion – A process that removes soil layers and carries them away from farmer's fields to bodies of water or other land resulting in the loss of valuable soil and its nutrients that are necessary for crops to grow. There are three primary kinds of erosion: wind, water, and tillage.

Soil Organic Matter – A soil indicator that measures the amount of soil organic matter, which consists of plant and animal decaying material.

Soil pH – Soil pH is the pH of soil water. A soil pH indicator measures the activity of hydrogen ions (H^+) in a soil solution. A neutral solution has pH 7 while an acid solution (acidic) has pH less than 7 (more H^+ than OH^-) and a basic (alkaline) solution pH larger than 7 (more OH^- than H^+)

Soil quality indicators – Soil quality indicators are physical, chemical, and biological properties, processes, and characteristics that can be measured to monitor changes in the soil.

Soil sample – A soil sample is a compost of the soil profile that has been dug out from a field, analyzed, and interpreted for it nutrient or mineral status.

Soil test – A soil test is used to determine the amount of a variety of essential nutrients in the soil, the pH value or how acidic or basic your soil is.

Soil Tilth – A soil indicator that refers to the physical condition, texture or structure, of the soil as it influences plant growth.

Soil Workability – A soil indicator which measures how easily the soil can be worked.

Water Holding Capacity – A soil indicator that measures the amount of water in soil that can be absorbed by plants. The capacity is measured between the high amount at full saturation or field capacity, and the low amount at the permanent wilting capacity.

Water Infiltration – A soil indicator that measures the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier.

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