New Mexico Soil Health Toolkit

Understanding and Assessing Soil Health to Implement Management Actions for Sustainable Soil Systems

October 2020

By Ken & Linda Scheffe

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Preface

This soil health toolkit was developed as an aid in instructing others in the management of soil health, as well as a guide or resource for farmers and ranchers wishing to understand their soils and plant communities better to manage the land for sustainable production, minimizing damaging off-site effects, and enhancing the ecology of the plant and animal communities.

The contents of this toolkit are not the ownership of the authors, contributors and editors, but rather a compilation of the knowledge, information, and tools from Universities, local, state, and federal governments, as well as experiences gleaned in working over the years with farmers and ranchers who actually manage our nation's soil, water, air, plant, and animal resources on a daily basis. Every attempt has been made to properly cite or credit the authors of materials in the various sections. Errors in proper citation of a source is unintentional and regrettable on our part.

Funding to produce this Toolkit is provided by direct support of the New Mexico Association of Conservation Districts (NMACD) and its leadership, through a Conservation Innovation Grant from the USDA Natural Resources Conservation Service.

The authors and editors wish to specifically acknowledge the support of Ms. Debbie Hughes, Executive Director of NMACD, Ken Leiting, and the NMACD Board of Directors.

Citation or reference to this toolkit should be as follows:

> Scheffe, Kenneth F. and Scheffe, Linda Oyer, PhD, *New Mexico Soil Health Toolkit, Understanding and Assessing Soil Health to Implement Management Actions for Sustainable Soil Systems*. A compilation of published and unpublished materials, 2020.

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Introduction

The purpose of this toolkit is to introduce a stepwise management approach and technical resources which can be adapted and integrated in maintaining healthy soil under various agricultural uses. Soil health is a concept that embodies several physical, chemical, biological, and hydrologic conditions and functions that soils serve in the natural environment and as a medium for the agricultural production of food, fiber, timber, energy, and other products. Maintenance of soil health is essential to the sustained use and economic viability of agricultural operations.

"Soil Health" is not rocket science – it is much more complex. Maintaining soil health involves physical, chemical, biological, hydrologic, and climatic variables all acting simultaneously, and changing with time. The redeeming quality of soil in this complex system is it strives to reach its best healthy condition when we cease activities which harm its essential functions and support the maintenance of conditions which allow it to function properly.

Stated simply, the soil health will be at its best when we unwittingly stop activities which cause harm and implement actions which support its functions in the environment and as a medium that supports agricultural production.

This toolkit is designed to assist farmers and ranchers implement management practices and other actions which will improve and sustain soil health. It consists of a series of steps to be followed to identify:

1) the objectives of the farming or ranching operation,
2) the assets and liabilities impacting any actions to be taken,
3) a means of assessing the health of the soil looking at several indicators,
4) the condition or health of the soil resource and what factors need improvement,
5) a process to identify and prioritize alternative practices and management to improve soil health,
6) the decision process in selecting the most effective options
7) specific instructions and methodologies to implement the desired management actions, and,
8) a means of following up to assess the effect of the practices on improving soil health and sustainability, and as needed, adjust the management as indicated by the change in the indicators of soil health.

Background

The United States is fortunate to have some of the richest and most expansive soils in the world that are well suited to agricultural production. These soils owe their origins to the forces that have shaped the continent. The tectonic uplift and wearing down of the rocks forming the eastern and western mountains of North America has provided an abundance of primary minerals which break down into plant essential nutrients. In addition, erosion and deposition acting with the climate and glaciation have created a palette upon soils have formed. The cool to warm moist climate has supported vast forests and prairies underlain by microorganisms which have further aided in the disintegration of primary minerals and cycled them through the topsoil and subsoil over the millennia.

Soils do fine and are healthy without any help from humans. Soil health is a measure of the soil's ability to perform its functional roles in the ecosystem. These roles are accomplished in concert and as a balance between the climate, their inherent fertility, and the plants and organisms that live in and upon the soil. Soils partition precipitation into runoff into streams and rivers and infiltration, some of which finds its way to aquifers and springs, and a measure that is captured and held in the soil and used by plants and organisms. The soil also serves as an important media that supplies nutrients and support for higher rooted plants and as habitat to soil macro and microorganisms. Another especially important role of soil is it provides the habitat for microorganisms to break organic and recycle plant residues as well as other compounds which would otherwise accumulate and become noxious in the soil (animal remains and waste).

The soil is a vast reservoir of primary minerals, plant nutrients, organic compounds, and the organisms that facilitate the functions of soil and keep the system in balance. This vast reservoir permits the soil to continue to function (i.e. "be healthy") even if withdrawals are taken from the soil. Withdrawals naturally occur with percolating waters removing some nutrients to deep aquifers or springs feeding rivers and streams. Other withdrawals occur with the occurrence of fire which removes organic compounds and minerals in the soot, smoke, and oxidation products, or the ash is blown or washed away with erosion following fire. Another of the withdrawals from the soil is by the animals which feed upon the plant community. Much of the nutrient is returned and redistributed, but certainly some is removed to other sites and soils.

Prior to the industrial revolution of the late nineteenth and early twentieth century, human's ability to make withdrawals from the soil were pretty much limited to his/her strength, endurance, and that of a few domesticated animals that could be brought to bear to manipulate the soil for the production of the desired plant community. However, the directed and repeated growth and harvest (removal) of selected crops on a discrete piece of land desired for the first time had the ability to drain the abundant soil reservoir of its nutrients. At that time, the only options regarding depleted soil was to regenerate using animal and green manures, or to vary the crops being grown, or to abandon the land and move to other land. This last option was of course both labor intensive to clear new ground, and often civilly unacceptable as often the other lands had claims by other peoples which could lead to wars.

With the industrial revolution, humans greatly expanded their capacity to manipulate and exploit the soil resource. Machine tractors powered by fossil fuels pulling large plows gave humans the ability to turn under the native vegetation and plant a monoculture of cash crops and to also transport these crops (and the soil nutrients they contained) vast distances with no return to the soil. Because of the nature and size of the machines, often not only the best and most fertile soils were disturbed and exploited, but also integrated soils of lesser capacity to produce the desired crop and with little

resilience to recover. These soils were quickly exhausted of their reservoir of nutrients and capability to grow the desired crop and often abandoned to erosion or influx of undesirable species.

Humans are intelligent and industrious. They realized that plant vigor and growth was often limited by the quantity of three primary nutrients in the soil – nitrogen, phosphorous, and potassium. However, with their intelligence and ingenuity coupled with development of complex machines in the industrial revolution, they could acquire the phosphorus and potassium through mining mineral reserves, and with the power of fossil fuels and magic of chemistry could create the needed nitrogen nutrient out of thin air- literally!. This gave humans unprecedented power to further extract the additional mineral reserves and energies of the soil with little concern to return nutrients, not to mention to allowing restoration of the conditions which enable the soil to fulfill the appropriate functions in the ecosystem. The coup de gras in human's domination of the soil resource came with the development and widespread use of pesticides (herbicides and insecticides) to protect the cash crop from competition by weed competition, insect damage, and microbial diseases.

So, this is how we got where we are today. We have soils which still have an abundance of primary minerals and a climate well suited to producing an abundance of vegetation, but because of exploitation, they (the soils) suffer a deficit of readily available plant nutrients exhausted using monoculture cropping and technology. The soil structure disrupted by continuous tillage such that the hydrology, the partitioning of precipitation into infiltration or runoff, is heavily skewed in favor of runoff, and finally the soil suffers from the loss of its microbial population having been decimated by depletion of organic matter and the addition of pesticides.

As bad as all this sounds, we can make decisions and take actions which will allow the soil to become healthier and to resume critical ecosystem functions and even to grow the crops we desire. Mostly, we just need to stop doing the things that reduced the soils' capacity to work for us. The soil does not depend upon human's assistance to be healthy – humans depends upon healthy soil to meet their needs.

Just what are we talking about regarding actions to sustaining a healthy soil that will sustain us. There are 5 principles of soil health. First, keep it covered. Don't leave it barren and exposed to sun and erosive forces of wind and water. Minimize disturbance (cultivation, improper grazing, chemical) which destroys soil structure, disrupts hydrologic functions and living organisms. Third, grow a diversity of plants that provide food and habitat to a diversity of organisms. Fourth, keep a living root in it. Soils left in a fallowed condition are basically holding their breath awaiting a living plant to cycle its nutrients and feed microbial populations. Finally, when, and as possible, integrate livestock and wildlife onto the landscape to assist in the nutrient cycling, and for the redistribution and integration of seed stocks in native plant communities.

We have the knowledge, technologies, and have choices we can make in allowing soils to return to healthy and functioning systems. Our agricultural production and capacity to feed and clothe the nation depends upon our ability to sustainably work within the capacity of our natural resources including the maintenance of healthy soil.

Soils 101 – A Basic Definition of the Nature, Character, and Functions of Soil

Soils 101 – A basic summary of the relationships of soil properties and qualities and their importance in agricultural use and production (topography, mineralogy, morphology, chemistry, physics, microbiology, hydrology, etc.).

Introduction

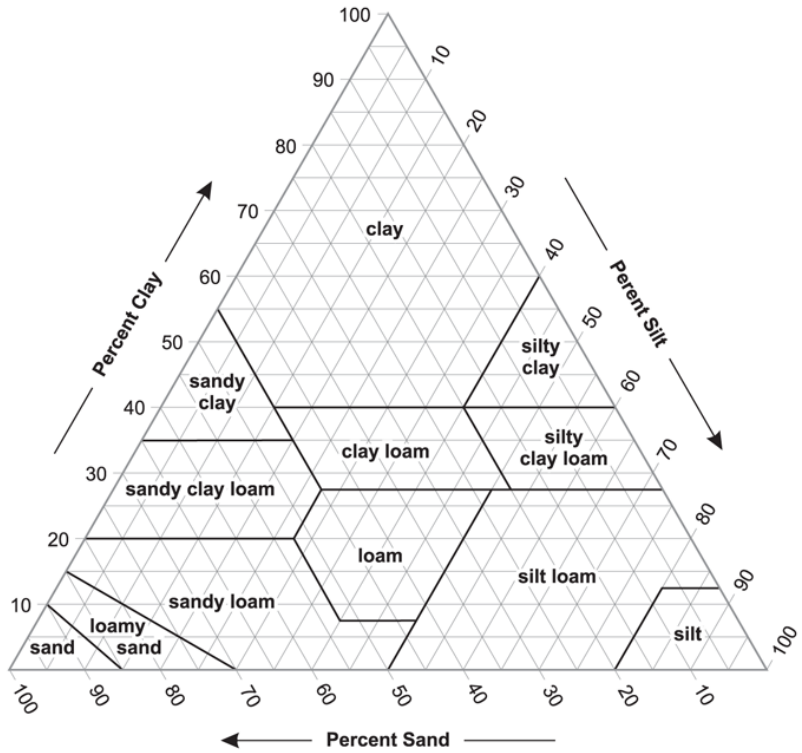
The term "Soil" has several meanings depending upon the use of it, and how it is to be used. To the civil engineer, it is a construction material. To the hydrologist, the medium that partitions rainfall into runoff or infiltration. To the average urban homeowner, the stuff that must be swept up off the floor. To the farmer or rancher, it is the medium which they work to produce crops or grow food for livestock. The exact nature and composition of soil is generally not well understood, nor does it need to be for many users. Their concern is generally that whatever the soil does for me, that it keeps on doing it. Few realize that their use of the soil impacts its functions and ability to continue to function to meet their needs. Soil consists of solids (minerals), liquids (water and solutes) , gases (air, CO2, N2, O2), and living organisms.

Minerals -Sand, silt, clay of various mineralogy, coarse fragments of rock, organic detritus, salts and other precipitates, oxides of metals derived from the breakdown and disintegration of various kinds of rock, including the precipitation of weathering products or dissolved compounds released by weathering. The proportion of the various soil minerals determine to a large degree the observable physical properties of the soil. While sand and silt are most commonly finer sizes of typical rocks and common minerals, the clay-sized particles in soils are one of several unique mineral forms called phyllosilicates that are formed by the recrystallization of ions into layers of sheet-like forms. The dissolution and recrystallization of common bedrock minerals in the sand and silt fraction form clay particles which impart unique properties on the soil and provide for the capacity to hold and release the plant nutrients minerals.

Liquids – typically water (or ice), and solutes dissolved in it, including sugars, and other organic compounds. These are held in pore spaces in the soil or adsorbed onto the surfaces of mineral grains.

Gases – 'soil air' (oxygen, nitrogen, carbon dioxide, and related organic compounds). Carbon dioxide and water vapor are generally higher in soil than in the atmosphere.

Living organisms – Living organisms includes both plants and animals as well as microorganisms. Included in the soil are living organisms such as bacteria, virus', fungi, actinomycetes, etc., macro invertebrates (insects), amphibians, mammals, and rooted plants growing on and in it.



USDA textural triangle showing the percentages of clay, silt, and sand in the 12 basic texture classes.

How and why soils vary across the landscape

Soil is a complex and dynamic system that varies continuously in three spatial dimensions and the fourth dimension of time. The properties and qualities of soil and the general nature of its composition are a function of five soil forming factors. These factors being topography, time, parent material, climate and living organisms.

Topography relates to where the soil occurs on the landscape, whether on the side of a mountain, across an expansive plain, or in a flood plain or bog. The topographic position determines to a large degree the gain or loss of mineral material (erosion) at a site, and the hydrology the soil experiences such as whether precipitation infiltrates, runs off, or pools at the site.

Soils are altered by four soil forming processes (discussed later) that occur over time. The longer time that a soil is exposed to these processes in a single place, the greater the expression of pedogenic features (soil development) will be observed. The duration of time that soil minerals are exposed to the forces of weathering, decomposition and leaching loss, the less inherent fertility of the soil remain. Old stable soils in intense weathering environments may have lost significant amount of plant essential elements and minerals over time.

Parent material refers to the rock and mineral constituents that make up the soil, and alludes to its origin, organization, and even potential fertility. Parent material may include igneous rock such as basalt and ash from volcanoes or intrusive igneous rock such as granite. It may be sediments deposited in oceans such as limestones and shale, or lithified sand dunes or beach deposits. Often, parent

materials for a soil are mixtures of minerals and rock derived from previously existing soils that were transported by wind or water from one place to another. Climate is a highly variable factor in the development of the nature and character of soil.

Climate determines the weathering regime to which soil minerals are exposed. It also determines the nature and abundance of plants and microorganisms which act upon the mineral fraction to break it down into its constituent elements. Generally, the moister and more temperate the climate, the greater the weathering of rock into soil, the greater the development of soil pedogenic features, and more abundant the soil flora and fauna.

The fifth factor of the soil formation is the living organisms. Being the fifth is by no means and indication of the importance in determining the nature and character of the soil. Organisms living in and upon the soil through their actions catalyze the chemistry occurring in the soil. The breakdown of soil minerals into constituent plant essential elements is catalyzed by acids and other compounds produced by soil organisms. Roots of vascular plants and burrowing soil organisms serve to break up the soil providing pathways for the infiltration and movement of water. And finally, the decomposition products of organisms that lived on or within the soil are recycled into subsequent generations of organisms making the soil their home.

There are four soil forming processes which are generally recognized to occur in soil. These processes include additions, losses, transformations, and translocations. The additions are most commonly the addition or accumulation of organic materials (humification) at or near the land surface due to biologic activity. Other additions of atmospheric origin, such as dust, or mineral constituents dissolved in rainwater may be significant or recognizable in the soil.

Losses include the removal of elemental constituents and compounds from the soil system. This occurs when percolating waters from rainfall leaches dissolved salts and minerals completely out of the soil system. Another mechanism of losses from the soil system might be loss as oxidation products from fire, or offsite removal by animals. The addition of new soil material by wind or water deposition, or the loss of soil material through erosion are not considered a soil forming process, but rather agent of the soil forming factors described above.

Transformations are the results of weathering and decomposition of one mineral and formation of a new mineral within the soil. Most notable of this process is the formation of soil clays, *in situ*, within the soil. This occurs when primary minerals, typically of igneous origin, are weathered, dissolve, and then recrystallize into new mineral forms such as soil clays. Other soil minerals, mostly oxides of silica, iron, and manganese are formed in a similar manner in the soil.

The fourth soil forming process is translocation. Translocation is typically the downward movement of a soil constituent with by water moving through the soil. Clays and some silt are commonly translocated (illuviated) from upper layers of the soil to some depth within the soil as a function of percolating water. This illuvial process leads to the formation of argillic horizons in soils. Similarly, soluble soil constituents such as salts and calcium carbonate (lime) are readily dissolved near the soil surface, translocated, and reprecipitated in the same mineral formation depth with the soil system.

The Concept of Soil Health

Soils are healthiest before we disturb them by various uses. Ways in which our use of soil reduces soil health and function include:

1) Tillage and cultivation disturbance
2) Wheel and plowshare compaction (reduced infiltration/permeability)
3) Extraction and removal of nutrients
4) Additions of amendments to improve nutrient extraction by increasing crop yields
5) Additions of pesticides (herbicides, insecticides, fungicides, etc.)
6) Reduction of diversity in flora and fauna (monoculture cropping, pesticides, clean tilling, etc.)
7) Accelerate erosion by wind and water
8) Creating barren soil (no cover) (wide temperature swings, increase vulnerability to erosion).

Healthy soils exhibit the traits of resistance and resilience. That is, they resist changes in condition or dynamic properties bought about by use, and they exhibit resilience which is the ability rebound quickly from otherwise long-term damage under use.

Functions of Soil in the Environment

Soil Health is a measure of its capacity to fulfill its natural functions in the environment. The functions of soil listed below are those relevant to man's uses and needs.

Partition precipitation into infiltration and runoff

Precipitation, whether in the form of rainfall or snowfall has three potential routes as it moves through the environment. First, it may return to the atmosphere as water vapor through evaporation from the soil surface, or in the case of snow change phases directly from snow crystals directly to vapor phase through sublimation. Second, depending upon numerous factors including vegetative cover, slope, infiltration and rainfall rate, precipitation may almost immediately upon hitting the ground become part of the concentrated surface flow or runoff as small rivulets combine into larger and larger flowing bodies of water eventually entering permanent streams, rivers, and lakes. The third route precipitation or melting snowpack might take is infiltration into the soil surface and then permeating through subsoil layers and unconsolidated sands, gravel, and rock moved primarily downward by the force of gravity. A measure of the infiltrated water remains in the soil and available for plants, which when taken up often ends up back in the atmosphere through transpiration. Excess water that infiltrates but cannot be held in the soil (water holding capacity) moves downward to water tables and recharges aquifers, or eventually toward lower lying streams where it rejoins surface waters through spring flow. The partitioning of precipitation into the components of evaporation, runoff, and infiltration has tremendous impact upon local hydrology and the plant and animal communities in the vicinity. Under degraded soil health conditions, runoff (and consequent soil erosion) and evaporation may dominate the partition resulting in lower plant available water stored in the soil and lesser deep percolation of water to recharge groundwater resources and feed springs.

Soil health impacts the partitioning of precipitation. Several soil health indicators readily identified in the field provide clues to which of the dynamic soil properties have been affected by

improper use or management of the soil. These include penetration resistance, aggregate stability, soil stability, infiltration, bulk density, crust strength, OM content, EC, available water capacity, residue cover.

Penetration resistance is primarily a function of soil texture, moisture content, organic carbon content, activity of burrowing insects, presence of cementing agents or physical disturbance which destroys soil structure. Generally, soils with higher clay content or the presence of rock fragments have higher penetration resistance than loamy, rock-free soils, but this is a static property not affected by soil health and management actions.

Aggregate stability determines whether the soil surface aggregates will be broken down into individual grains which flow down between spaces of remaining aggregates and essentially seal the soil surface, often forming crusts when dry. Crusting on the soil essentially seals the surface denying precipitation access to macropores between aggregates that transmit water.

Organic matter content to a degree is a factor in determining the soil's ability to form water stable aggregates. Basically, the organic compounds form something of a glue that holds individual soil particles into aggregates. Without organic matter, the aggregates would tend to break down easily when the soil is wetted.

EC or electrical conductivity is a measure of the salinity. Salts in the soil often indicate an impaired hydrology, either one that is plugged such that water doesn't percolate and continuously remove soluble salts, or one for which there is upwelling of water to near surface where evaporation and transpiration remove water leaving salts behind, often as visible precipitates.

Available water capacity is a measure of the difference between total amount of water that can be held in the soil and how much water remains after when tension exceeds the plant's capacity to extract it and is generally a function of soil texture (sand, silt, clay) and aggregation. Lower than expected available water capacity for a specific texture class is an indicator of impaired soil health.

Residue cover impacts the partitioning of participation into infiltration or runoff by serving as a physical barrier between the falling raindrop and the soil surface. The velocity of raindrops striking the residue are slowed and thus reduces impact energy and the breakdown of aggregates which would plug macropores at the soil surface. In addition, residue on the soil surface creates a tortuous path for water to move downslope as runoff thus increasing retention time and the opportunity for infiltration.

<u>Site of storage of water and nutrients for higher plants (including cultivated crops)</u>

The consumptive use or water demand of many field crops typically ranges from about 0.1 to 0.4 inches of water per day during the growing season. Of course, it does not rain this amount every day, nor could irrigation be applied in an effective manner to meet crop needs daily, so the soil serves as a three-dimensional reservoir storing water to meet daily crop needs. Early in the growing season when demand is low, shallow near surface roots supply needs. As growth continues and demand increases, roots extend to greater depths and more broadly near surface to meet crop needs. Soils with the highest water holding capacity (medium textured, well structured, deep) might store as much as 7" water to the depth of deep-rooted crop and meet several weeks of crop demand between rainfall or without supplemental irrigation. However, soils and climates meeting these conditions (precipitation equals or

exceeds daily evapotranspiration) are few and far between, and even they are subject to cyclic wet or dry spells.

In forest or rangeland settings, plant communities have evolved to survive the droughts and thrive in the normal to wet years. As climate changes, those plants not adapted disappear and are replaced by different species adapted to the changed conditions.

Soil conditions affecting available water storage are slow to change over time. However, disturbances to the soil by, especially the soil surface (compaction, disaggregation, loss of cover), impact how effectively water infiltrates to become stored, as well as the ultimate volume of water which can be held.

Habitat for microbes, insects, and larger organisms

The soil serves as the only possible habitat for many organisms. In some cases, the mass of living organisms within the soil is greater than that of those living above it. Just from the standpoint of biological diversity, the soil as habitat is important, but more important are the functions and roles that soil organisms living within that habitat serve to the larger ecosystems and our own existence and well-being.

Microbes such as bacteria, actinomycetes, and fungi, break down or decompose organic detritus at and below the soil surface. Earthworms and similar macroinvertebrates ingest and further decompose organic materials. If not for them, organic debris would accumulate on the land and essential nutrients would be tied up, so microorganisms and soil invertebrates are responsible for much of the nutrient cycling we depend upon in agricultural production.

Additionally, species of bacteria, such as Rhizobium spp. form symbiotic relationships with plant roots to fix nitrogen in a plant available form which is essential for higher plant growth. Studies have shown that fungal hyphae also serve as extensive conduits for nutrient and moisture for rooted plants. Algae living on and near the soil surface generate their own energy from sunlight, further adding to the energy supply in the soil. Protozoa are the larger and more complex multi-cellular microorganisms also participating in the decomposition and recycling of nutrients.

Construction material and foundation for man's structures

In an agricultural setting, the soil serves as a foundation supporting rooted crops and the reservoir for water and nutrients. In a non-agricultural setting, soils often serve as foundations and as building materials for man's activities. The properties and qualities of the soil to a great extent determine what a site may be used for, and the cost of construction or maintenance of structures. Soils of high expansive type clays will heave when wetted and shrink and crack upon drying. Such cyclic movement from season to season can crack the foundations of building and across roads, cause breaks in underground pipes, and even result in failures of dams and levees. Sols that are very sandy or silty may not provide sufficient strength under load and shift when weight is applied on the surface and are highly susceptible to wind and water erosion due to low cohesion. Soils with high water tables have low strength and objects place upon them tend to sink with time, and soils that are frozen and include lenses of soil ice (permafrost soils near earth's poles) will thaw when covered with structures and roads and liquify resulting in complete failure.

Management to Sustain or Improve Soil Health

The concepts of soil health, soil productivity/capability, and soil sustainability are not analogous. The concept of a healthy soil is one that fulfills the functions and roles in the ecosystem to the optimum extent based upon the inherent soil characteristics and climate. A healthy soil would lack the indicators that outside disturbances impair its optimum functioning. Soil productivity or capability is a measure, or sometimes a prediction, of the yields of specific commodities or crops under a given agricultural system and levels of management. Sustainability is the concept of a soil's ability to continue to perform its ecosystem functions as well as meet the desired productivity goals under appropriate management.

It is possible to improve soil health, it is possible to increase soil productivity, and it is possible to manage a soil for sustainable use. However, improving the health does not necessarily mean you will experience higher productivity. Increasing productivity without proper management of other factors may degrade soil health and sustainability. Managing in a sustainable manner generally will at least stabilize soil health, maintain levels of production, but might be at increased cost or increased levels of management.

It should be noted that increasing productivity with the addition of supplemental irrigation or nutrient additions will also introduce the potential for new challenges which were not present without irrigation or fertilizer additions. For example, increasing the time and amount of plant available water with irrigation creates an environment that now also is idea for invasive species and weeds adapted to that higher moisture regime. The addition of plant nutrients may produce similar affects if the invasive species and weeds are better able to utilize the newly available nutrient before or more effectively than the desired crop. In addition, increased growth and biomass production will likely create an environment more friendly to pest species and diseases that were not experienced under lower levels of inputs and production.

When one or more factors limiting production are tweaked, you must be ready to react to the unintended consequences of changing the environment. Addressing these unintended consequences (e.g.- invasive species, weeds, insects, disease), will require greater time, greater levels of management, and increased cost that must be justified by the increase in productivity. In addition, there might be additional unintended detrimental effects to soil health if by treating the newly emerging issues such as invasive species, weeds, insects, and disease, results in greater disturbances to soil aggregation and structure, reduces populations and diversity of native soil organisms, and results in lowered organic matter levels in the soil. Managing soil health and sustained productivity for agricultural production requires awareness of and recognition of the potential negative impacts, and a willingness to implement the management necessary to effectively remedy the unintended detrimental impacts.

Soil has both static and dynamic properties

Static properties include texture, mineralogy, coarse fragments, depth (generally). These properties do not change appreciably on the human time scale under normal uses except if drastically disturbed by shaping, removal, or additions man-made materials or earthly materials from other sources. These properties do not change with management. That is, are not improved by soil health management, nor do they degrade (under normal circumstances) with poor management.

Dynamic properties include water content, temperature, reaction or pH, structure, fertility (plant nutrients), dissolved constituents, organic carbon, microorganisms, and plant communities. These properties change seasonally with the climate (moisture and temperature, and biologic activity), and also change with addition of agricultural amendments (fertilizers, pesticides), removal by crops and harvesting, or with cultural activities such as tillage, irrigation, traffic, and grazing, as well as other processes including fire, flood, and erosion/deposition. These are the properties which degrade under poor management and results in loss of function of the soil. It is the dynamic properties that are targeted in soil health management strategies.

Soil Health Indicators include:

Organic Carbon content - active (labile) carbon and stable carbon compounds

Organic carbon in the soil occurs in many forms from the living roots and microorganisms to freshly, but not decomposed plant matter, to highly decomposed and minimally reactive carbon compounds. In addition, a portion of the carbon pool in soil occurs as oils, sugars, and simple carbohydrates. These forms are most reactive and utilized by microorganisms.

The intent in managing the organic carbon stock in the soil is not necessarily to maximize it, but rather, provide a pool or organic carbon in various states of growth, degradation, and stable (humus) forms that support micro- and macro- organisms, plants, soil fauna and promotes development of stable soil aggregates. In most cases, soil organic matter content of a few percent (2-3% by weight) is enough for adequate soil functions related to agricultural production. Soil organic matter above a level of about 6% by weight can lead to undesirable conditions, such as soil acidity and unavailability of selected plant nutrients, low strength to support equipment, etc. In addition, it might be impossible depending upon the climate and soil moisture content to maintain more than a few percent organic matter in the soil under agricultural production.

Soil Structure

Soil Structure and the formation of soil aggregates facilitate the infiltration of precipitation and exchange gases between the soil and the atmosphere. In addition, soil aggregates create pathways that plants utilize in the elongation and extension of their root systems. Soil structure also creates crevices and pores that water can infiltrate and be held in for plant use. The soil structure reveals itself upon hand examination of specimens. The soil will tend to part or break along the edges of organized structural units. For any given layer in the soil, the size, shape, and durability of the structural units tends to be homogenous laterally, but become larger and more durable with dept, or replaced by coarser compound structural units.

Though not mutually exclusive or restricted to any one soil horizon or depth within the soil, the soil surface is usually dominated by granular to subangular block structural units of fine to medium size. Size or coarseness, and strength (durability) of soil structural units tends to increase with depth. Columnar and prismatic structure are usually found in the subsoil of well-developed soils. These are recognized easily typically as small open cracks or fissures running vertically in the subsoil. These compound soil structures often will part into smaller structural units of subangular block, or in the case of more clayey soils, angular blocks.

Structureless conditions may occur in soil due to natural conditions, or because of disturbances by human activities. Structureless, single-grained conditions are often found in very sandy soils lacking sufficient silt, clay, and/or organic matter to form stable aggregates. Excessive tillage of sandier soil can also break down weak granular or subangular blocky units into single grains. A structureless massive condition can occur in in practically any soil texture. In this case, the soil mass has no preferred planes that it parts along when examined. This is occasionally expressed in very young or recently deposited soil sediments (immature soil), or soils that have been disturbed by cultivation, heavy traffic, or experienced mass movement such as human transport or landslides.

When a soil lacks organized aggregation, it is said to have structureless massive condition. In such a condition, the infiltration of water is greatly slowed such that most precipitation is lost to surface runoff, and significant topsoil is lost to erosion. In addition, the exchange of soil gases is greatly retarded to the detriment of microorganisms and roots in the soil. Soils with massive structure also greatly limit the extension of root systems dramatically reducing availability of soil moisture and access to plant essential nutrients.

Salinity (range and effects)

Salinity in soils is caused by the accumulation of the chlorides and sulfides of sodium and calcium. Salinity in the soil is generally not an issue for most crops when in the electrical conductivity (EC) ranges from 0-2 ds/m, but becomes problematic above EC 4, and generally prohibitive to any crop above EC of 8. In most circumstances, the accumulation of salts in the soil that previously was not salt affected by its position in the lower portions of the landscape (swale, draw, floodplain) is due to poor or inappropriate management of soil drainage or irrigation applications. In the case of irrigation management, the quality of the incoming water used for irrigation may be the primary cause of soil salinity. In most cases, soil salinity is managed by creating drainage within the soil below the rooting zones of affected crops, or through the improved management in the application of irrigation water.

Reaction (pH range and its effects)

Soil reaction (pH) has its greatest impacts in the availability of plant nutrients. If much lower than optimum (pH 6.5-7.5), it is likely that calcium, magnesium and phosphorus and other basic cations could be deficient or unavailable to plants. If too high (>8.2) then iron, zinc, manganese, and other metallic plant nutrients are held in an unavailable state to the plants. Some specific crops might prefer a soil reaction that is slightly acidic or slightly basic. Maintenance of a soil pH in the optimum range enhances most crop plants and microbial populations. Soil fertility testing is necessary to determine the nutrient status of the soil and to troubleshoot nutrient imbalances.

Biological diversity (species and abundance)

The abundance and diversity of biological species in the soil is a measure of the soil's health. Looking at it from the other side, the presence of only small populations of only a few species of soil organisms is a prime indicator of a soil with significant issues related to soil health and its capacity to fulfill important functions in the ecosystem.

Photosynthesizers (plants, algae, bacteria) capture energy by using solar energy to fix carbon dioxide and adding organic matter to soil. Decomposers (bacteria, fungi) break down residue.

Mutualists (bacteria, fungi) enhance plant growth. Pathogens and Parasites (some bacteria, fungi, nematodes, microarthopods) promote disease. Root-feeders (nematodes,macroarthropods) consume plant roots and reduce yields. Bacterial feeders (protozoa, nematodes) and fungal feeders (nematodes, microarthropods) graze, release plant available nutrients and control many root-feeding or disease-causing pests. Shredders (earthworms, macroarthropods) break down residue and enhance soil structure. Higher-level predators (nematode-feeding nematodes and larger arthropods, mice, voles, shrews, birds, other above-ground animals).

From the USDA-NRCS (available from Soil and Water Conservation Society) -***Soil Biology Primer***:

Bacteria enhance soil health:

- Feed other members of the soil food web
- Decompose organic matter
- Help keep nutrients in the rooting zone and out of surface and groundwater
- Enhance soil structure, improving the flow of water and reducing erosion
- Compete with disease-causing organisms
- Filter and degrade pollutants as water flows through soil

Fungi enhance soil health:

- Decompose complex carbon compounds
- Improve accumulation of organic matter
- Retain nutrients in fungal biomass, reducing leaching of nutrients out of the root zone
- Physically bind soil particles into aggregates
- Are an important food source for other organisms in the food web
- Improve plant growth when mycorrhizal fungi become associated with the roots of some plants
- Compete with plant pathogens
- Decompose certain types of pollutants

Protozoa enhance soil health:

- Release nutrients stored in microbial biomass for plant use
- Increase decomposition rates and soil aggregation by stimulating bacterial activity
- Prevent some pathogens from establishing on plants
- Provide prey for larger soil organisms, such as nematodes

Nematodes enhance soil health:

- Regulate the populations of other soil organisms
- Mineralize nutrients into plant-available forms
- Provide a food source for other soil organisms that influence soil structure
- Consume disease-causing organisms

Arthropods enhance soil health:

- Improve soil structure through burrowing and the creation of fecal pellets.
- Control disease-causing organisms.
- Stimulate microbial activity.
- Enhance decomposition through shredding of large plant litter and mixing of the soil.
- Regulate healthy soil food web populations.

Earthworms enhance soil health:

- Shred and increase the surface area of organic matter, thus stimulating microbial decomposition and nutrient release.
- Improve soil stability, porosity, and moisture holding capacity by burrowing and aggregating soil.
- Turn soil over, prevent disease, and enhance decomposition by bringing deeper soil to the surface and burying organic matter
- Improve water infiltration by forming deep channels and improving soil aggregation
- Improve root growth by creating channels lined with nutrients.

Plant and biological diversity is essential to consider when designing a crop rotation/cropping system. Utilize continuous no-till, crops with high levels of residue, cover crops, mulches, manure, or other organic materials to improve organic matter and improve soil microbial population. Use diversified crop rotation by increasing the number of crops in different functional groups (i.e. warm season grass, warm season broadleaf, cool season grass and cool season broadleaf) used in rotation; Conservation Crop Rotation (328). This will help increase soil organic matter, keep living roots year-round, keep soil covered year-round, diversify the soil microbial population, improve biological activity, improve nutrient cycling, and provide integrated pest management. Reduce use of pesticides to the extent possible, only apply pesticides that meet economic threshold. Instead, use cultural, mechanical, biological IPM methods. Integrated Pest Management (595). Promote integrated crop-livestock integrated system to improve soil fertility and biological activity.

Sources of Information and data useful in managing soil and other natural resources

The USDA-NRCS **Web Soil Survey** is a free, web-based primary source of publicly accessible soils maps, descriptions, interpretations, plant community, and other data.

> *Web Soil Survey (WSS) provides soil data and information produced by the National Cooperative Soil Survey. It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world.*

https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

An aerial view map showing the locations of fields and physical features of the farm or ranch is an essential tool in managing the land and documenting cropping systems, conservations measures implemented. Additionally, a plan map developed using the Web Soil survey can help locate and denote such features as soil type and vegetative communities, as well as showing the locations of resource problems such as poor drainage, salinity, excessive erosion, and other production limiting features.

The NRCS Web Soil Survey is an invaluable tool to aid in the development of a farm or ranch map. It Includes an aerial photographic background, civil and cultural features, roads, and other map data. In addition, a coverage or layer of soil types can be overlain onto the photo base map. Additionally, map overlays and tabular data can be created showing soil chemical and physical properties, capabilities and/or limitations for various agricultural and engineering uses, yields potentials of common crops, and potential native plant communities (ecological sites). The various maps, overlays, tabular and even spatial (GIS) data can be saved and downloaded in report and database form from the Web Soil Survey Site.

Specific instructions on operating the Web Soil Survey are found on the opening page of the web site, and a brochure can be downloaded, and there are also numerous YouTube© videos on developing soil and interpretative maps and obtaining information on soil properties and qualities using the WSS.

The NRCS Kellogg Soil Survey Laboratory Database . . .

> The Charles E. Kellogg Soil Survey Laboratory (KSSL) is the key source for soil analytical data for the National Cooperative Soil Survey (NCSS). The KSSL receives samples from soil survey project offices located throughout the continental United States, Alaska, and Hawaii as well as from cooperating partners at universities and other government and non-government organizations.

https://ncsslabdatamart.sc.egov.usda.gov/

The NRCS National Water and Climate Center Database . . .

The National Water and Climate Center (NWCC), located in Portland, Oregon, supports the **Snow Survey and Water Supply Forecasting Program** and **Soil Climate Analysis Network (SCAN) Pilot Program**. As part of the USDA's Natural Resources Conservation Service, the NWCC is responsible for producing and disseminating accurate and reliable **water supply forecasts** and other climatic data to its wide variety of users.

All the data collected at the National Water and Climate Center are quality-controlled and placed in a comprehensive database known as the **Water and Climate Information System (WCIS)**. In addition to the data collected through the automated **SNOTEL** and **manual snow data collection** processes, the NWCC also incorporates precipitation, streamflow, and reservoir data from the U.S. Army Corps of Engineers (USACE), the U.S. Bureau of Reclamation (BOR), the Applied Climate Information System (ACIS), the U.S. Geological Survey (USGS), various water districts and other entities into the Water and Climate Information System database.

https://www.wcc.nrcs.usda.gov/

Additional information regarding the description of soil properties and qualities, soil interpretations and the information presented in USDA soil survey reports can be found in the Soil Survey Manual, Ag. Handbook #18. It is available from the NRCS Distribution center and can also be viewed online or downloaded.

Soil Science Division Staff. 2017. Soil survey manual. C. Ditzler, K. Scheffe, and H.C. Monger (eds.). USDA Handbook 18. Government Printing Office, Washington, D.C.

https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054262

Selected Resource Settings and Agricultural System Settings in New Mexico

Knowledge of the resource setting is critical in understanding the sustainable use and management of the land. The resource setting includes not only the types and properties of the soil and the topography, but also characteristics of the climate including frost free season, seasonal temperature ranges and precipitation, prevailing winds, weather extremes, plant communities (ecological sites), and the availability of other natural resources such as groundwater or surface waters which might be used for irrigation.

On a regional basis, natural resource settings (topography, climate, water resources, soils) often support adapted agricultural systems (grazing, cropland, irrigation). Development of scenarios of the various combinations provides for a beginning point in identification of management systems and practices useful to address soil health issues. The following scenarios highlight the major agricultural and natural resources settings for targeting development of soil health management systems and sustainable agricultural operations. Additional systems and settings may be developed as needed.

New Mexico Soil Health Agricultural Setting Scenarios

1) Pecan/Pistachio Orchard -Southern Desert Valley (MLRA 42)

This area is primarily in the Rio Grande Valley between T or C and the TX state line and from in the Tularosa Basin from Alamogordo northward toward Tularosa. Orchards are typically commercially grown without cover crops using flood or drip irrigation as a requirement for production. Due to water quality and soil salinity concerns, an irrigation leaching requirement to remove accumulating salts must be maintained. Primary threats to sustained production include lack of sufficient quality irrigation water, salinization, urban encroachment (and its limitations), and conversion.

2) Apple Orchard, High Elevation, Mountains (MLRA 36, 39, 48)

Typically, high elevation (>6,000 ft) orchards including, but not limited to apples, cherries, and similar fruit. Basically, the small, generally family owned garden plot to small farmer's market orchards associated with mountain snowpack runoff for irrigation. Acreage is generally small, markets are somewhat limited, and most producers do not rely on their fruit production as a primary income source. Many are limited resource producers. Primary production concerns are disease, weather/climate damage, lack of sufficient irrigation, and loss of land to conversion.

3) Dryland Wheat/Livestock Grazing Operation (MLRA 77)

This cropping system is most often found in the northeastern part of the state where rainfall permits non-irrigated annually tilled cropping systems. Tracts are generally large and have associated rangelands on the operating unit. Some may be cow-calf operations, but most will be stockers. Operators will full time and often having hired ranch hands or perhaps absentee owned with full time manager. Primary concerns are the rising cost of production/low market prices, loss of supplemental irrigation water sources, erosion hazard (wind), and socioeconomics of producers including age, family interests, return on investment, etc.

4) Irrigated Alfalfa-Small Grain - Long Rotation (River Valleys)

This is the dominant cultivated cropping system utilized in most of the reservoir irrigated river valleys. Alfalfa hay is grown, perhaps with other pasture grass mixtures, and is grazed by the operator's livestock, or cut, baled, and marketed for dairies, feedlots, horse owners, or shipped out of state. Threats to continued sustainable production include lack of irrigation water, poor market prices, part-time operators, ownership turnover, and loss of agricultural infrastructure to support production.

5) Vegetable Crop Rotation (Onions, Garlic, chile, Lettuce, etc.)

Vegetable crops are principally grown commercially in the southern Rio Grande Valley in NM, but also an important industry locally to farmer's markets in the northern Rio Grande, Pecos, and San Juan valleys. Other areas of limited vegetable production can be found in the Uvas Valley, San Juan Valley (NAPI), and smaller tracts on the High Plains. Probably want to check into splitting this case study into an "Organic Grown" case study and "traditional cropping" case study. Sustained production concerns include disease losses, demand for soil/water resources to grow CAFO feedstock, limited local markets, labor demands, complexity and intensity of management required. The supporting agricultural infrastructure and technical support is strong.

6) Specialty Crops – Flowers, Nursery Stock, Tree Farms

Limited in extent but is of high economic value. Most often occurs in irrigated crop settings in floodplains associated with larger municipalities along river systems. These crops are typically not 'organically' grown and because of the cash value of individual plants may be more subject to prophylactic application of agricultural chemicals to combat pests and to accelerate plant growth to achieve to earliest marketable size possible. In other words, probably the most susceptible agricultural system to extreme overapplication of pesticides and nutrients which could enter surface and groundwater resources, impact pollinators, wildlife, and adjacent native plant communities.

7) Improved Pasture/Hayland - Mountain Valleys

These areas are principally in the higher elevation mountain valleys on small private parcels surrounded by national forests. Many are managed directly by owners who supplement, or perhaps enable, agricultural activity by income from off-farm employment. Typically, the commodity produced is consumed locally by on-farm domestic livestock. Principal concerns would include undependable irrigation water supply, lack of skill/time for adequate management, depredation by wildlife, and lack of agricultural infrastructure and support.

8) Cotton-Peanut-Small Grain Rotation - Eastern High Plains (MLRA 77C/D)

Larger agricultural producers on the eastern to southeastern plains typically with supplemental irrigation available. Operations are large and utilize many of the agrichemicals available for pest and disease management. Wind erosion is probably the major annual resource concern with an emerging resource concern over irrigation water availability in the near- to long-term. These are generally highly erosive soils, expansive areas already in CRP, and most immediately vulnerable to climate change (warmer/drier). Soil health is probably less resilient here than most other areas of the state (perhaps excluding Deming/Lordsburg areas).

9) Milo/Corn – Center Pivot Irrigation (MLRA 77C)

Two general areas in this resource setting include the northeastern high plains and the NAPI project in NW New Mexico near Farmington. Principal assets are their productive soils, abundant irrigation water source, developed agricultural infrastructure, and perhaps a more sophisticated management schema/capacity by resident managers. Principle concerns would be erosion, poor agricultural markets, and perhaps weather hazards. Continuous cropping, lack of crop diversity, and a tendency to look to agrichemical solutions.

10) Organic, Community Garden Vegetable Production (Farmer's Market)

Very small-scale production reaching niche markets. Most interested in attracting the chic, financially well-off consumers providing 'peace of mind' human and pet foods. Appearances, environmental impacts, and holistic management are important to these producers and their customers. Customers are eco-savvy and politically empowered. Less than optimal production and some pest damage are acceptable as they distinguish themselves from traditional agricultural operations. Interested in maintaining the 'field to table' connection. Of course, opt for holistic management of pests, organic sources of fertilizers, and probably most open to new approaches, technologies, and ideas. Located near larger metropolitan areas.

11) Hayland/Pastureland w/Manure Management (CAFO Operation)

This scenario represents the farms using manure from large cattle feedlots and dairy farms common throughout the state. The CAFO operations typically provide manure solids or liquid waste from containment ponds and to nearby farms and ranches where it is land applied as a plant nutrient. Occasionally, the CAFO may have the acreage base and operate the land application themselves. Most times, the availability of manure and wastewater nutrient sources outpaces local demand so application above crop demand is a concern. Regulations do not demand that the waste products be tracked or applied at beneficial use rates. These farms are typically along the Rio Grande or Pecos Rivers, or on the High Plains around Clovis, Portales, or Clayton, or affiliated with NAPI near Farmington. Resource concerns are numerous and include odor, air quality, dust, and both surface water and groundwater contamination through runoff and leaching (salts, N, P).

12) Livestock Grazing Operation – Southern Desert (MLRA 42)

Cow-calf or stocker ranching operations under this scenario often include large tracks of federal land grazing leases (USFS and BLM) critical to the economic viability of the operation. Carrying capacity is generally low at 35-100 acres/animal unit. Supplemental drinking water sources for livestock are required. Resource concerns include wind erosion, brush infestation (creosote, mesquite), drought (low carrying capacity), and loss of plant diversity.

13) Livestock grazing operation – Pecos and Canadian Basins (MLRA 70)

Cow-calf or stocker ranching operations under this scenario often include small to medium tracts of grazing leases (State and BLM) supporting economic viability or the operation. Carrying capacity is moderate at 25-35 acres/animal unit. Encroachment and infestation by brush (mesquite and juniper) are critical resource/management concerns and noxious weeds to a lesser extent. Wind erosion can become a concern with overgrazing as well as water erosion (rill and gully). Fire and re-seeding are viable management tools.

14) Livestock grazing operation – Colorado Plateau (MLRA 35)

Livestock herds here are more diverse than other parts of the state and include more sheep, goats, and horses in the mix. Many ranches include significant tracts of USFS, BLM, or BIA grazing leases. Some grazing is communal. Operations are generally small to medium sized and carrying capacity of the land is 25-50 acres/animal unit. Livestock water is limiting and infestation by sagebrush, juniper, and noxious plants a major concern. Water erosion due to overgrazing can be severe and wind erosion around homesteads a concern. Producers in this area generally have less control over the land and more limiting resources for conservation implementation. Sheltering of livestock in winter months is a concern. Language and culture are included in the challenges to conservation implementations.

15) Livestock Grazing Operation – High Plains (MLRA 77)

These ranches are typically stocker operations grazing yearlings for the beef market. Livestock may be moved to winter grazing on wheat pasture during winter months. Operating units are large with little to no federal grazing leases, but often include some tracts of state grazing lease. Soil resources and livestock water are usually not limiting. Rangelands are generally diverse and support moderate stocking requiring 10-15 acres/animal unit. Infestation by cholla and mesquite are concerns. Water erosion (gully) can be a problem near drainage systems.

16) Livestock Grazing Operation – Mountains (MLRAs 38, 38, 48B, 49)

These ranches are typically cow-calf or stocker operations and provide summer grazing only. Winter snowpack and harsh conditions permit utilization for only 4-8 months/year. Forage production is generally high, but the terrain is generally rugged. Drinking water is adequate, but livestock control can be challenging. Federal and state grazing leases dominate the landscape and are critical to economic viability. Resource concerns include water erosion, loss of plant diversity, and noxious weed infestation.

Steps Needed to Develop Sustainable Soil Systems

Objectives, Assets, Inventory, Concerns, Opportunities, Alternatives, Decisions,

Implementation, Effects, and Impacts

The key approach to achieving integrated sustainable management is to think system (ecosystem, whole farm, and watershed), think critically (connect the dots), actively seek resource opportunities, emphasize technology "exchange" vs. "transfer" with other producers and partners, plan creatively and flexibly, and focus on keeping energy flow through the integrated system. A reemphasis on biological factors is also necessary since recent agriculture has essentially forgotten biological, but rather focused on chemical and physical factors. Using agro-ecological principles and improving soil health is key to improving soil, water, air, plant, and animal resources. Case studies, field trials, on-farm research/demonstrations, farmer-to-farmer networks are some of many important components of successful technology exchange and outreach. Interdisciplinary teams including producers and partners are essential in developing integrated sustainable farming systems. Development, implementation, and ongoing evaluation of a comprehensive conservation plan and accurate recordkeeping serve as necessary management tools.

Soil Health Planning Checklist

STEP	SUMMARY	COMPLETE
1. Farmer or Rancher Objectives	Identify history of land use. Define objectives for farming, soil health, sustainable system.	
2. Identify Assets and Liabilities	Identify assets and liabilities for farm/ranch.	
3. Inventory and Analyze Resources: Assessing Soil Health	Collect background information. Determine which methods/indicators best meet the farmer/rancher needs. Do soil health assessment. Determine soil health and other soil, water, air, plant, animal, energy and human resource concerns and opportunities.	
4. Identify Resource Concerns, Problems and Opportunities	Identify general resource concerns, problems, opportunities, needs. Consult SWCD long-range plans, soil maps, other resources.	
5. Develop Alternatives: Implementing Steps to Improve Soil Health	Formulate alternatives to meet the farmer/rancher goals, address natural resource problems, and improve or protect resource conditions. Take advantage of opportunities and meet the social, economic, and environmental needs of the whole farm/ranch within the watershed.	

6. Evaluate alternatives and make decisions	Consider effects of alternatives, including ecological, natural resource, social, cultural, and economic impacts; size of farm; type of operation; resource availability. Predict consequences of various practices and operations. Consider environmental laws and regulations.	
7. Implement management actions and conservation plan	Apply relevant practices in the conservation plan. Seek technical assistance and support.	
8. Evaluate the Plan: Following Up	Identify improvements, deficiencies and any changes in operation, objectives, design needed. Be flexible to changing needs.	

<u>Step I</u> – Farmer or Rancher Objectives

Though it might seem to be obvious in many cases, determination of the specific objectives of the farmer or rancher should be addressed. While it is obvious that production of a commodity for positive economic return and remaining in business is a requirement to survive, often other objectives are brought into focus once feeding the family is met. These objectives might be to pass the operation over to one of the children, or to protect natural resources, both on and off site. It may be to enhance habitat for game or other native species. Often it is also to feel pride in being a good steward of the land. Regardless, it is necessary to identify the objectives and write them down. Once written, they are real, and can be evaluated whether they are being met.

It is important to know how we got where we are regarding this farm or ranch. We need to ask, "What is the history of the land?", and "What has been the land use, agricultural development activities, and land alterations on this farm or ranch unit?" We need to walk the road back to what was here when it all started. Develop the background and history of the physiographic and climatic setting, ownership and historical land uses and any alterations that provide insight to how we got where we are today. (Soil Bank, CRP, Dust Bowl, when first sodbusted and irrigated, Land Grant/acequia, logging, etc.)

Why are you engaged in agriculture?

Primary livelihood (income), preferred lifestyle, self-reliance/independence, better life/opportunities for heirs, environmental concerns, other.

What do you want the outcome of your actions to be?

Sustainable farming operation for heirs; healthier ecosystem; reduced offsite impacts; greater food independence in US; other.

What are some of the agricultural challenges that your community is facing?

Unpredictable changing climate, declining yields, invasive species, diminishing irrigation water (groundwater or snowmelt), weak market for commodities, development (loss) of agricultural lands,

lack of access to or cost of agricultural support services (equipment, amendments, fuel, maintenance/repair), lack of access to information and education, other.

Do you have a current recognized issue you wish to address and correct?

Declining production, increasing debt, resource degradation, spiraling costs, loss of labor, operational support, other.

Are you certified organic or are you transitioning to an organic operation?

Are there any marketing, resource, or watershed opportunities of which you would like to take advantage?

Step II – Assets and liabilities

It is critical to know what is available and what must be acquired for implementation of management strategies, as well what else might be competing for resources such as time and money. Listing the assets and liabilities is necessary to develop a balance sheet.

Assets - Include land, cash reserves and investments, equipment, livestock, infrastructure, partnerships and business operations, experience, education, family members working the operation

Liabilities – Payments and rentals on land, payments on equipment, tax assessments and user fees, costs of seed, fertilizer, chemicals, and fuel, equipment maintenance costs, labor costs.

Holistic Financial Planning: Planning for Financial Success has been included as a potential resource.

Step III – Inventory of resource conditions and capacities (Resource Assessment)

The resource assessment is an in-field identification and determination of the condition of the soil and vegetative resources, as well as the condition of supporting infrastructure such as fences, irrigation ditches, etc. It includes observation and noting location of eroded areas, wet/saline spots, etc. Also need to note minor soils with limitations (shallow depth, gravelly, limy) that would affect its use described in the producer's objectives.

Collect background information. Determine which methods/indicators best meet the farmer/rancher needs. Do soil health assessment. Inventory soil health and other soil, water, air, plant, animal, energy and human resource concerns and opportunities.

Conservation Planning Technical Note No. 2 provides guidance on "Sustainable Agricultural Systems Planning, Evaluation and Outreach".

Sustainable Agricultural Technical Note No. 1 provides "Cropland Inventory Worksheets for Sustainable Systems Planning". This technical note provides conservationists and producers with a series of worksheets to assist with the inventory process when providing integrated systems planning assistance on cropland. They are designed to record and organize information from the producer in a manner that documents current crop management and provide for the inventory necessary to analyze benchmark conditions and develop feasible alternatives.

The worksheets include:

1. Crop Rotation and Crop Management
2. Tillage Equipment and Tillage Sequences
3. Crop Nutrient Inputs
4. Integrated Pest Management
5. Irrigation Management and System Description
6. Erosion Factors for Land Treatment Practices
7. Animal Feeding Operation Inventory
8. Other Considerations for Sustainable Cropping Systems Inventory

Agronomy Technical Note No. NM-80 provides instructions and considerations for "Cropland In-Field Soil Health Assessment" to be used to assess compaction, soil organic matter depletion, aggregate instability, and soil organism habitat loss or degradation resource concerns.

Develop a soil map and conservation plan and map with the assistance of a certified conservation planner. Web Soil Survey can be used to assist with the development of a soil map with soil health interpretations.

<u>Step IV</u> – Determination of resource concerns/problems/opportunities

Obvious problem areas (erosion, wet spots) will be easiest to identify and require a corrective conservation practice to remedy along with continued management to prevent recurrence. The less obvious issues such as low vigor, stunted growth, low plant density, disease or insect infestation will require greater assessment and additional analyses. Appropriate field tests should be conducted to determine cause(s) of the concerns/problems.

Additionally, look for opportunities which take advantage of resource conditions which do not lend themselves to alteration to better suit primary objectives. Such conditions might be flooding hazards, high water tables, etc. These might be best utilized as buffers, wildlife habitat, or recreational use rather than production row crop agriculture. It may be possible to introduce new cropping systems, such as fruit trees, berry, grapes on soils or sites not suited to the primary production objective. Also, if there are any resource opportunities in the watershed, such as a composting facility, available manure, etc. that could be utilized on the farm without high cost of transport, these should be considered.

Effective application of sustainable agricultural systems requires looking beyond resource problems. While examining the whole operation, planners and producers need to be alert to potential resource opportunities that exist on the land and in the watershed. Planners and producers must think in terms of resource efficiency. Effective planning for sustainable agriculture seeks to use locally available resources as production inputs and reduce use of external or remote resources. This promotes reduced input costs and improved efficiency of resource use. Planners and producers must consider both on-site and off-site effects of conservation management systems to reduce adverse effects to the environment.

Some of the key questions to ask include:

- What are the natural resources on farm? How can these be used more efficiently?
- What resource opportunities exist throughout watershed?
- What crops can I grow? Marketing niche/opportunities, climatic considerations, agro-ecological needs, etc.
- How is water quality on the farm for all purposes? Have I minimized runoff and leaching?
- How can I protect air quality, including reducing dust, odor? (See Appendix, Air Quality: New Mexico Air Quality Tech Note No. 1, Air Quality Assessment Tool and New Mexico Air Quality Tech Note No. 5, Cropland Air Quality Practices)
- Am I using crop rotations for nutrient cycling and to reduce disease/pest problems?
- What type of livestock/wildlife exists or could be raised?
- Besides using crop residues, manure, legumes, compost, cover crops, what other practices can be applied to build soil health? To recycle nutrients? To use water efficiently?
- Which practices would contribute to an environmentally and economically sound farm?
- How can I conserve/produce energy or reduce energy use?

- How can I maximize biodiversity, including:
    - Integrate crop and livestock production, use hedgerows, insectary plants, cover crops, etc. to attract beneficial insects, bats, and birds
    - Plant trees and perennial crops
    - Abandon monocropping in favor of crop rotations, intercropping and polycultures
    - Manage pastures to support diverse selection of forage plants
    - Plant cover crops

- How to manage pests ecologically, including: (See Appendix – Integrated Pest Management: Water Quality Technical Note 20, New Mexico Guidance for Integrated Pest Management)

- Prevent pest problems by building healthy, biologically active soil, creating habitat for beneficial organisms, and choosing appropriate plant cultivars/rotations
    - *Tolerate, don't eradicate*
    - *There is no silver bullet*
    - *Treat the causes of pest outbreaks, not the symptoms*
    - *If you kill the natural enemies, you inherit their job*
    - *Pesticides are not a substitute for good farming*

Step V – Development of alternatives to consider

This is a melding of the objectives and capacities of the producer, the existing conditions needing corrected or amended, and the capacity or suitability of the resources. Often, there will be only spots or sites that need corrective actions such as stabilization or drainage, but entire fields/farm will require a change in management actions, generally to stop doing something, or to start doing something. Alternatives must all be reasonable and acceptable actions that could be implemented by the producer. Do not develop unacceptable alternatives just to sell the one remaining that you think they should implement. If resource conditions present do not support the desired goals and objectives of the producer, be prepared to develop and to discuss possible options that are supported by resources available, including soils, irrigation (or lack of), climate, and other resources.

Consider the entire ecosystem and the farm within the watershed, including the on-site and off-site impacts of alternatives. Also, do not promote one conservation practice to improve one resource if it will deteriorate another resource (for example water quality and water quantity).

The “Healthy Productive Soils Checklist for Growers” provides core practices for developing a soil health management system. A soil health management system is a system of conservation practices that maintains or enhances soil health by addressing soil health principles. These principles include minimize disturbance, maximize soil cover, maximize biodiversity, maximize presence of living roots. The core practices for the soil health management system include Conservation Crop Rotation, Cover Crop, No Till, Mulch Tillage, Mulching, Nutrient Management, Integrated Pest Management. Irrigation

Water Management, Prescribed Grazing, Forage and Biomass Planting and other practices may be considered essential to achieve the producer's objectives and address resource needs and opportunities.

The NRCS NM document (Dan Bloedel), "Conservation Practices that Address the Soil Health Planning Criteria and Promote a Soil Health Management System (SHMS)" is included. It provides a matrix of how surface and subsurface soil health indicators may be affected by conservation practices.

Agronomy Technical Note 81 provides a "Small Farmer Crop Rotation Plan Guide" to help achieve improved soil health with greater diversity of plant species and crop rotation.

Soil Health Technical Note No. 450-04 is included on "Addressing Resource Concerns with Conservation Practices within Integrated Soil Health Management Systems on Cropland".

The document (Linda and Ken Scheffe), "Soil Health Resource Issues and Opportunities Related to Potential Causes and Management Recommendations to Improve Soil Health", will help identify better the cause of the soil health issue or identify soil health opportunities and recommend specific practices to improve soil health.

Step VI – Decision making and documentation

To help choose the appropriate conservation practices to include in the soil health management system, the producer can refer to the "Conservation Practice Talking Point Fact Sheets" included. These include definition of the conservation practice, potential positive and negative effects of the practice on soil, water, air, plant, animal, human and energy resources. Conservation practices include Composting Facility, Conservation Crop Rotation, Cover Crop, High Tunnel System, Integrated Pest Management, Irrigation Water Management, Mulching, Nutrient Management, Prescribed Grazing, Residue and Tillage Management (Reduced Till), Residue and Tillage Management (No Till), Salinity and Sodic Soil Management, and Upland Wildlife Habitat Management. Other conservation practices can be included as requested. The fact sheets also include the net effect of the practice as well as commonly associated practices to be used in a system.

The producer must weigh the benefits and the costs of implementing each of the alternatives. Needs to include skills needed, equipment required, costs and time to perform the actions, and even potential risks (drought, insects, commodity price, etc.). Do not lead the farmer/rancher to settle on decision for which they are not comfortable or cannot achieve.

The conservation practice talking point fact sheets contain general talking points for the conservation planner to discuss with the producer. It is the first step towards an economic or financial analysis. The second step would include identifying a specific site for analysis at the farm or field level, editing the template for local conditions, adding units and quantities of farm inputs and outputs. The third step in the economic analysis is to place a dollar value on as many variables as possible, put all units in the same time frame, using amortization ($/Acres/Year) or net present value ($/Acre), so benefits and costs can be compared. The fourth and final step would be to combine several conservation practices into a conservation system, which is how most conservation practices are applied

at the field level. Data for the worksheet comes from the producer, conservation planner, technical specialist and local agricultural supply vendors and contractors. See "Economics Technical Note: TN 200-ECN-1, Basic Economic Analysis Using T-Charts (August 2013)" for more information. An example of the conservation effects worksheet is also included.

Step VII – Implementation of management actions and conservation practices.

This is a continuous, evolving, and iterative process.

a. Identify specific task to be accomplished and the management actions and practices to be used to achieve it.
b. Develop list of practices- Include Definition, Purpose, and Description of how to implement
c. List the tools and resources needed to implement decisions
d. Implement the actions
e. May need thorough description of actions, Tech Notes, step-by-step instructions

The "Cover Crop (NRCS conservation practice 340) Spreadsheet" provides the cover crop species selection table depending on the crop rotation and objectives, suggested seeding periods, and implementation requirements for New Mexico.

This and all conservation practice standards, specifications and implementation requirements are available from your local NRCS office. These detail how to implement the practice within a soil health management system.

The "Soil Health Assessment Worksheet" is provided as an example of recordkeeping for soil health assessments. This would need to be created and adjusted for each site-specific need.

The "New Mexico Guidance for Integrated Pest Management Water Quality Tech Note 20" is provided to promote and keep records for integrated pest management which will improve soil health.

Other resources, including soil health assessment and interpretation, soil fertility assessment and interpretation, irrigation water quality sampling, cover cropping, grazing management, soil biology, residue management, and soil health are included in the Appendix.

Step VIII -- Follow-up evaluation of results.

Identify improvements, failures, and any changes in operation needed. Use soil tests, inventory techniques, and other analytical tools to quantify improvements. Based upon results of the evaluation need to modify, adopt new, or abandon failing management practices. Need to emphasize that the needed practices and management strategies will change as the resources improve and other secondary objectives and needs take precedence. Sustainable management is a dynamic process that continuously looks for the deficiencies and takes actions to correct them and looks to achieving new levels of performance.

The conservation plan documents the objectives, resource concerns and opportunities, soil health and other assessments, and all the conservation practices and management actions which may change with changing needs, objectives, weather, land uses, opportunities, and other components.

Be flexible and creative with the planning process to redesign and implement the conservation plan to address changing needs and take advantage of changing opportunities. Think outside the box and realize that there is no limit to your potential. Planners need to be innovative, creative thinkers and design systems which are flexible enough to accommodate changing social, economic, cultural, and environmental conditions. Always use an integrated systems approach (ecosystem, field, whole farm, watershed).

Evaluation of need, design, implementation, and impact are all essential to the process; yet, often most of these are omitted from the comprehensive process. Without proper evaluation at all phases, a plan/project may not properly function and address the needs/concerns/issues identified. Criteria, tools, and ongoing mechanisms should be established for each type of evaluation. Recordkeeping is an excellent management and evaluation tool so that changes can be made when needed.

Prior to developing a sustainable agriculture plan/project, an evaluation of need should be conducted. This can be done by numerous methods, including producer surveys, observation, scoping meetings, etc. An evaluation of design should always be fully studied also to ensure that the objectives are clearly defined and will be met and that the plan/project will have positive impacts. Implementation evaluation is the phase which is most clearly understood and most conducted. It ensures that a practice/system is constructed/applied according to design but does not address how effective or how well designed it is. Evaluation of impact or evaluation of the success and effectiveness of the sustainable system is based partially on achieving a loop effect or a balanced ecosystem. Potential and actual negative and positive impacts should be evaluated. It is often the most forgotten and costly of the evaluations, yet one of the most important, since this can lead to a multiplier effect of negative results.

Case studies, field trials, on-farm research/demonstrations, field days, farmer-to-farmer networks are some of many important components of successful technology exchange and outreach. These can also serve in assisting in several of the evaluation types.

There are many types of case studies, including comparing a benchmark condition to a planned condition and showcasing integrated approaches/practices/systems/technologies. Criteria, target audience, method should be established prior to developing case studies to ensure achieving targeted objectives.

Field trials and on-farm research/demonstrations serve to ground-truth on-station research and provide an effective method for planners, consultants, universities to exchange/test technology with producers. Farmer-to-farmer networks, tours, international exchanges are also very effective outreach methods.

Appendix

Resources Include: (Useful conversions and calculations, Illustrations/photos (how to perform specific tasks), Sources of equipment, materials, chemicals, services, Fact sheets, Tech Notes -NRCS, and various other sources, Linkages to online and published references and resources, Copies of data sheets and other forms)

a. Grazing Management (Grazing Management and Soil Health)
b. Soil Health Assessment (including Soil Health Guides for Educators, Soil Quality Indicators, Soil Quality Tech Note 450-03, Indicators and Lab Procedures)
c. Whole Farm Planning (Whole Farm Conservation Best Practices Manual)
d. Cover Cropping (including various articles and publications; Cover Cropping for Pollinators and Beneficial Insects, Cover Crops for Sustainable Crop Rotations, Intercropping Principles and Production Practices, Managing Cover Crops Profitably, Principles of Cover Cropping for Arid and Semiarid Farming Systems, Soil Health Response of Cover Crops in Winter Wheat-Fallow System)
e. Soil Health Implementation (including book references and articles; A Soil Owner's Manual, Basics and Benefits, Discover the Cover, Do Not Disturb, Green Cover Seed Soil Health Resource Guide, Principles for High Functioning Soil, Soil Health Article – Successful Farming August 2019, Soil Health Put to the Test - Soil Health Digest October 2019, Soil Health Literature Summary of Effects of Conservation Practices, Understanding Soil Health for Production Agriculture in NM)
f. Soil Fertility and Irrigation Water Quality (including Appropriate Analyses for New Mexico Soils, Carbon to Nitrogen Ratios in Cropping Systems, , How to Collect and Interpret Plant Tissue Samples, How to Collect Soil Samples, Interpreting Soil Tests, Soil Fertility Interpretation Irrigation Water Sampling, Irrigation Water Quality Guidelines,)
g. Soil Biology (including Soil Biology Primer, Soil Biology and Land Management)
h. Residue Management (Benefits of Conservation Tillage, Conservation Tillage and Soil Health, Residue Management with Cover Crops)
i. Air Quality (Assessment Tool, Cropland Air Quality Practices)
j. On-Farm Energy (Clean Energy Farming, NRCS Solar Energy Primer, NRCS Wind Energy Primer, NRCS Energy Estimators, including Animal Housing, Irrigation, Nitrogen, Tillage available at https://energytools.sc.egov.usda.gov/)
k. Integrated Pest Management (Backyard Beneficial Insects for New Mexico, Bee Guide New Mexico, Beneficial Insects of New Mexico, IPM for Home Gardeners, New Mexico Guidance for IPM Water Quality TN 20)
l. Irrigation Water Management (Purpose of NM Integrated Water Management Handbook, IWM Resource Inventory, Estimated Soil Moisture by Feel and Appearance, Planning for Irrigation Water Management, Choosing an Irrigation System)

Soil Health Glossary

The Soil Science Society of America, Madison WI maintains an Internet Glossary of Soil Science Terms.

Soil Health Terms (including soil properties, soil health indicators, and assessment terminology)

https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/?cid=nrcs142p2_053848#quality

aggregate stability	The ability of soil aggregates to resist degradation. An aggregate is many soil particles held together in a small mass. In a "well-aggregated soil" the aggregates and pores between them hold up well to forces such as rain, wind, and compaction. (Compare to slake test.)
amoozemeter	A tool that uses a constant head of water to measure the rate of water movement in a saturated soil, and thus estimates saturated hydraulic conductivity.
anthropogenic	Generated by humans. Used to indicate soil conditions, disturbances, or stresses that are created by people.
assessing soil health	Estimating the functional capacity of soil by comparing a soil to a standard such as an ecological site description, a similar soil under native vegetation, a reference soil condition, or quality criteria. The objective of the assessment dictates the standard to be used. (Compare to monitoring.)
attributes of soil change	Quantifiable properties used to describe the nature of soil change, including drivers, types, rates, reversibility, and pathways of change.
available water capacity	Loosely, the amount of water available for plants to use. Specifically, the volume of water released from soil between the time the soil is at field capacity (the maximum water held in soil against the pull of gravity) until the time it is at the wilting point (the amount of water held too tightly in soil for commonly grown crops to extract). Loamy soils and soils high in organic matter have the highest AWC.
baseline	The initial soil condition before monitoring soil quality over time. Subsequent measurements on the same soil are compared to the baseline measurement.
benchmark soil	A benchmark soil is one of large extent, holds a key position in the soil classification system, or is of special significance to farming, engineering, forestry, livestock production, or other uses. The purpose of benchmark soils is to focus data collection and research efforts on soils that have the greatest potential for expansion of data and interpretations.
bulk density (Db or BD)	The density of soil, i.e., the weight of soil divided by its volume. The BD of agricultural soils normally ranges from 1.0 to 1.6 g/cm3.
cation exchange capacity (CEC)	The capacity of soil to hold nutrients for plant use. Specifically, CEC is the amount of negative charges available on clay and humus to hold positively charged ions. Effective cation exchange capacity (ECEC) is reported for acid soils (pH<5). Expressed as centimoles of charge per kilogram of soil (cmol/kg).
cotton strip assay	Measures the amount of biological activity as determined by the degree of degradation of a standardized strip of cotton buried in the soil.
disturbance	An event or its change in intensity or frequency which alters the structure or functional status of an ecosystem. Examples of disturbances that can affect soil include drought, fire, harvest, tillage, compaction, overgrazing, or addition of pesticides.

dynamic soil properties	Soil properties that change over the human time scale in response to anthropogenic (management, land use) and non-anthropogenic (natural disturbances and cycles) factors. Many are important for characterizing soil functions and ecological processes and for predicting soil behavior on human time scales. (Compare to use-dependent soil properties.)
electrical conductivity (EC)	How well the soil conducts an electrical charge. EC is a measure of salinity, generally expressed as decisiemens per meter at 25ºC (dS/m).
fatty acid analysis	Examination of the fatty acid methyl esters (FAMEs) in the soil using gas chromatography. Fatty acids are within the cell walls of soil organisms, so the types of fatty acids found in soil are an indicator of the structure and diversity of the soil community.
function	A service, role, or task that meets objectives for sustaining life and fulfilling humanity's needs and is performed by soil or an ecosystem. (Compare to soil function.)
functional capacity	The quantified or estimated measure of physical and biophysical mechanisms or processes selected to represent the soil's ability to carry out the function.
human time scale	That portion of the pedogenic time scale that covers periods of centuries, decades, or less.
hydraulic conductivity (Ksat)	A quantitative measure of how easily water flows through soil. (Compare to infiltration and permeability.)
indicator of soil quality	A quantitative or qualitative measure used to estimate soil functional capacity. Indicators should be adequately sensitive to change, accurately reflect the processes or biophysical mechanisms relevant to the function of interest and be cost effective and relatively easy and practical to measure. Soil quality indicators are often categorized into biological, chemical, and physical indicators.
indicators of soil quality, biological	Measures of living organisms or their activity used as indicators of soil quality. Measuring soil organisms can be done in three general ways: 1) counting soil organisms or measuring microbial biomass, 2) measuring their activity (e.g. soil basal respiration, cotton strip assay, or potentially mineralizable nitrogen), or 3) measuring diversity, such as diversity of functions (e.g. Biolog plates) or diversity of chemical structure (e.g. cell components, fatty acids, or DNA). Each approach provides different information.
indicators of soil quality, chemical	These include tests of organic matter, pH, electrical conductivity, heavy metals, cation exchange capacity, and others.
indicators of soil quality, physical	Physical characteristics that vary with management include bulk density, aggregate stability, infiltration, hydraulic conductivity, and penetration resistance.
infiltration rate	The rate at which water enters soil. (Compare to hydraulic conductivity.)
inventory	The systematic acquisition of resource information needed for planning and management.
microbial biomass	The total amount of organisms in the soil, excluding macrofauna and plant roots. Microbial biomass is typically determined through substrate-induced respiration, or fumigation-extraction methods.
minimum data set (MDS)	The smallest set of soil properties that can be used to characterize or measure soil quality. The MDS will vary based on the intended land use, soil type, and climate. The first MDS was suggested by Larson and Pierce and included the following: nutrient availability, total organic C, particle size or texture, labile organic C, plant-available water capacity, soil structure, soil strength, maximum rooting depth, pH, and electrical conductivity.
monitoring soil quality	Tracking trends in quantitative indicators or the functional capacity of the soil in order to determine the success of management practices or the need for additional management changes. Monitoring involves the orderly collection, analysis, and interpretation of data from the same locations over time. (Compare to assessing.)
organic matter	Any material that is part of or originated from living organisms. Includes soil organic matter, plant residue, mulch, compost, and other materials.

organic matter, active fraction	The highly dynamic or labile portion of soil organic matter that is readily available to soil organisms. May also include the living biomass. Particulate organic matter (POM) and light fraction (LF) are measurable indicators of the active fraction. POM particles are larger than other SOM and can be separated from soil by sieving. LF particles are lighter than other SOM and can be separated from soil by centrifugation.
organic matter, stabilized organic matter	The pool of soil organic matter that is resistant to biological degradation because it is either physically or chemically inaccessible to microbial activity. These compounds are created through a combination of biological activity and chemical reactions in the soil. Humus is usually a synonym for stabilized organic matter but is sometimes used to refer to all soil organic matter.
pedotransfer function (PTF)	A mathematical relationship between two or more soil properties that shows a reasonably high level of statistical confidence. PTF's are used to predict difficult-to-measure soil properties from readily obtained properties of the same soil.
penetration resistance or penetrability	The ease with which a probe can be pushed into the soil.
permeability	The qualitative estimate of the ease with which fluids, gases, or plant roots pass through soil.
pitfall trap	A small container (trap) buried so the rim is at the level of the soil surface. It is used to catch soil arthropods that move across the ground surface.
porosity	The volume of pores in a soil sample divided by the bulk volume of the sample. Air-filled porosity is the fraction of the bulk volume of soil that is filled with air at any given time or under a given condition, such as a specified soil-water content.
potentially mineralizable nitrogen (PMN)	A test measuring the amount of soil organic nitrogen converted to plant available forms under specific conditions of temperature, moisture, aeration, and time. It is a measure of biological activity and indicates the amount of N that is relatively rapidly available.
primary ecological processes	Ecological processes including the water cycle (the capture, storage and redistribution of precipitation), energy flow (conversion of sunlight to plant and animal matter), and the nutrient cycle (the cycle of nutrients such as nitrogen and phosphorus through the physical and biotic components of the environment).
processes	Physical, chemical and biological mechanisms that follow fundamental scientific laws. Examples include pedogenic processes, geomorphic processes, and ecological processes.
reference soil condition	The condition of the soil to which functional capacity is compared. . Soil quality is usually assessed by comparing a soil to a reference condition. The reference condition may be data from a comparable benchmark soil, baseline measurements taken previously on the same soil, or measurements from a similar soil under undisturbed vegetation, or under similar management.
scoring function	A standardization procedure used to convert measured values or subjective ratings to unitless values usually between 0 and 1. This allows all soil property measurements to be integrated into one value or index for soil quality. The four general types of scoring functions used in soil quality assessments are: more is better (higher measurements mean higher soil quality, e.g. SOM); less is better (lower measurements mean higher soil quality, e.g. salinity); optimum range (a moderate range of values is desirable, e.g. pH); undesirable range (a specific range of values is undesirable)
slake test	A measure of disintegration of soil aggregates when exposed to rapid wetting.
soil change	Temporal variation in soil at various time scales at a specific location.
soil function	Any service, role, or task that soil performs, especially: 1) sustaining biological activity, diversity, and productivity; 2) regulating and partitioning water and solute flow; 3) filtering, buffering, degrading, and detoxifying potential pollutants; 4) storing and cycling nutrients;

	and 5) providing support for buildings and other structures and to protect archaeological treasures. (Compare to function, functional capacity.)
soil health or soil quality	The capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation. In short, the capacity of the soil to function. There are two aspects of the definition: inherent soil quality and dynamic soil quality. (Compare to functional capacity.)
soil health, dynamic	That aspect of soil quality relating to soil properties that change as a result of soil use and management or over the human time scale.
soil health, inherent	That aspect of soil quality relating to a soil's natural composition and properties as influenced by the factors and processes of soil formation, in the absence of human impacts.
soil organic matter	The total organic matter in the soil. It can be divided into three general pools: living biomass of microorganisms, fresh and partially decomposed residues (the active fraction), and the well-decomposed and highly stable organic material. Surface litter is generally not included as part of soil organic matter.
soil resilience	The capacity of a soil to recover its functional capacity after a disturbance.
soil resistance	The capacity of the soil to maintain its functional capacity through a disturbance.
soil respiration	The amount of carbon dioxide given off by living organisms and roots in the soil.
soil respiration, basal	The level of carbon dioxide given off by a soil sample. Basal respiration is a measure of the total biological activity of microorganisms, macroorganisms, and roots.
soil respiration, substrate-induced	A measure of the carbon dioxide given off by a soil sample after adding sugar or other food. It is used to estimate microbial biomass in the sample.
soil structure	The arrangement of soil particles into aggregates which form structural units. Size, shape, and distinctness are used to describe soil structure. Farmers often describe soil structure with words such as crumbly or cloddy.
tilth	The overall physical character of soil regarding its suitability for crop production.
use-dependent or management-dependent properties	Soil properties that show change and respond to use and management of the soil, such as soil organic matter levels and aggregate stability. This is a narrower term than dynamic soil properties which encompasses all changes on the human time scale including those induced by natural disturbances or cycles.
use-invariant properties	Soil properties that show little change over time and are not affected by use and management of the soil, such as mineralogy and particle size distribution.
water holding capacity	The amount of water that can be held in soil against the pull of gravity.