Manual

Soil Health Survey

MO DIRT Soil Health Survey Manual

This manual is a product from the Missouri Transect: Climate, Plants and Community. This is a project of Missouri EPSCoR (Experimental Program to Stimulate Competitive Research), a Research Infrastructure Improvement Track 1 (RII Track-1) grant funded by the National Science Foundation.

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This material is based upon work supported by the National Science Foundation under Award Number IIA-1355406. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Introduction

The Missouri Transect project, funded by the National Science Foundation EPSCoR program, uses different scientific approaches to study and predict the impact of climate change on agricultural productivity and native vegetation in Missouri, and how stakeholder communities are likely to be affected by and respond to the challenges of a changing climate. Important components of The Missouri Transect are public education and outreach efforts. **MO DIRT** - **M**issourians **D**oing **I**mpact **R**esearch **T**ogether, is a citizen science initiative that crowdsources the collection of data on soil health and reciprocal soil-climate interactions across Missouri. This project includes a citizen science project to assess soil health indicators over time among different land uses at the state level. The ultimate goals of this citizen science initiative are to educate citizens on soil science research, to conduct research on soil health and the soil-climate interface, and to train citizens on data collection, analysis, and reporting of scientific results.

Soil health surveys are conducted by individuals or small groups, all of whom are equipped with training, guidelines, and soil test kits. The participants collect data on indicators of soil health and soil-climate interactions including: temperature, color, texture, respiration, bulk density, water content, percent water-filled space, nutrients, pH, active carbon, and organic matter. Committed participants are asked and expected to continue monitoring their survey sites monthly for ten months of the year. MO DIRT offers training to conduct soil health surveys and manage data. A web-based portal is available to access educational and training materials and to share science data. The data collected by the citizen scientist is available for download to be used for teaching purposes, land management decision making, and research on the health status of Missouri soils.

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The advice and unconditional support of several soil scientists have made these soil health surveys possible. We acknowledge the contributions to the MO DIRT program and manual by:

- Dr. Kristen Veum, Research Soil Scientist, USDA-ARS, Cropping Systems and Water Quality Research Unit, Columbia, Missouri
- Dave Skaer, retired Area Resource Soil Scientist (Southeast Missouri), USDA-NRCS.
- Dr. William F. Brinton and Lucas Rumler, Solvita, Woods End Laboratories, Mt. Vernon, Maine
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Background

SOIL HEALTH

Soil health is the capacity of soil to function as a vital ecosystem that sustains living organisms, their processes, and environmental quality. Healthy soils have the ability to perform five essential functions:

- Sustaining biological diversity, activity, and productivity.
- Regulating water through infiltration and storage.
- Filtering, buffering and degrading organic and inorganic materials.
- Cycling and storing nutrients and carbon.
- Providing physical stability and support.

In order to measure soil quality, or the capacity of the soil to function effectively, soil indicators are used. These are soil property measurements that can detect changes in the functions or processes of concern. Some indicators are inherent soil properties that do not change with management because they have been established over thousands of years (e.g., soil texture, type of clay, depth to bedrock). Other indicators are dynamic properties of the soil that can change within a year or season, and are dependent on human management and natural disturbances over decades to centuries (e.g., soil respiration, soil temperature).

Evaluating soil health involves the examination of physical, chemical, and biological indicators. Understanding soil health allows us to assess and manage the soil so that it can function optimally, and future degradation of this precious natural resource can be prevented.

Improving soil health implies maintaining suitable habitats for soil organisms by reducing soil disturbance, increasing plant diversity, keeping living plants in the soil as long as possible, and keeping the soil cover with vegetation all the time. Soil maintenance, consequently, will increase the productivity and profitability of soils. Humans are dependable on healthy soils that provide them with critical resources (food, fiber, fuel, medicines, chemicals, materials). In addition, soils offer economic benefits for land managers, valuable resources for future generations, and a healthy environment.

The following indicators of soil health will be measured during the soil surveys: air and soil temperature, soil respiration, soil water-filled pore space, water content, bulk density, soil fertility (nitrogen, phosphorous, potassium), pH, active carbon, soil color, soil texture, and organic matter.

INDICATORS OF SOIL HEALTH

Soil color

Soil color is an indicator of various chemical processes acting on soil. These processes include the weathering of geologic material, the oxidation-reduction reactions on soil minerals (mainly iron and manganese), and the decomposition of organic matter. Climate, physical geography, and geology influence these processes.

Soil color can be used to estimate the organic matter content of the soil, to indicate the effects of human disturbance and past vegetation, to identify, classify and evaluate soils, and to locate where the soil water table is, among many other soil activities.

There are two primary coloring agents in soil: organic matter and iron. Dark surface soil usually indicates high content of organic material, while shades of red, yellow, and gray usually relate to the quantity and form of iron present.

Color development and distribution of color within a soil profile are part of weathering. Also, as organic matter decomposes into black humus, it coats surfaces of soil as it permeates through the soil. Humus color decreases with depth, and iron pigments become more apparent. So, as depth below the surface soil increases, colors become lighter, yellower, or redder. See Table 1 below for the interpretation of soil colors.

The Munsell System of Color Notation (www.munsell.com) is a system used to compare soil colors anywhere in the world. This system helps scientists to be consistent in the interpretation of colors. It has three components: hue (specific color), value (lightness and darkness), and chroma (color intensity) that are arranged in books of color chips. Soil samples are held next to the chips to find a visual match and assigned the corresponding Munsell notation. For example, a brown soil may be classified as: hue value/chroma (10YR 5/3).

Table 1. General interpretation of soil colors

SOIL COLOR	DUE TO THE PRESENCE OF:	COMMENTS
Dark or black	Organic matter	Mostly found at soil surfaces. Associated with well-aggregated soils with above-average nutrient levels.
Clear or white	Calcium and magnesium carbonates, soluble salts or high proportion of sand (quartz crystals)	May indicate considerable leaching and low organic matter.
Red and bright yellowish	Iron is oxidized and not hydrated with water	Under dry conditions or well-drained soils. The iron oxides have strong surface charge properties that promote good aggregation of soil particles with sufficient porosity to allow air and water for root development.
Yellowish brown/orange	Less oxidation of iron and hydration	Average air and moisture conditions.
Mucky soil mass or clay with spots of red, yellow, and gray colors	Ferrous and ferric compounds	In soils that are waterlogged for at least one part of the year, or due to the activity of plant roots living in ponds under water.
Grey/green/bluish-grey	Iron and manganese in reduced state	In waterlogged soils leaching oxygen with colorless forms due to the loss of pigments.

Soil texture

Soil texture is described by the presence and relative proportions of the three types of particles that make up soil: sand, silt, and clay. These particles differ in size as follows (Table 2):

Table 2. Soil particle classification according to the International Society of Soil Science

Diameter of the particles (mm)	Classification
> 2	Stony structure
2 – 0.2	Coarse sand
0.2 – 0.02	Fine sand
0.02 – 0.002	Silt
<0.002	Clay

Depending on their texture, soils will vary in their ability to retain water and nutrients. A simple way to examine soil texture is to physically handle dry and wet soil samples, using your fingers to work with small soil samples. *Sandy soils* feel rough (gritty) because sand particles have hard edges. These soils do not hold many nutrients because they have large pores that allow gases and water to move through them rapidly. The *sand* particles do not adhere to each other and cannot stay together. *Silty soils* are smooth and powdery, and when wet, they make crumbles or ribbons, but are not sticky. Silty soils have smaller pore spaces than sandy soils, therefore, they can hold more water. *Clayey soils* are smooth when dry and sticky when wet, making balls or ribbons that stay together. Because their particles are so small, clayey soils can hold a lot of nutrients, water, and gases.

Most soils contain different combinations of sand, silt, and clay. The Soil Textural Triangle (Figure 1) shows the twelve possible soil classes based on the relative percentages of these combinations of textures. The most appropriate soil class for plant growth is loam, which can absorb water very efficiently. The loam soil is composed of mostly sand and silt, with a smaller amount of clay.

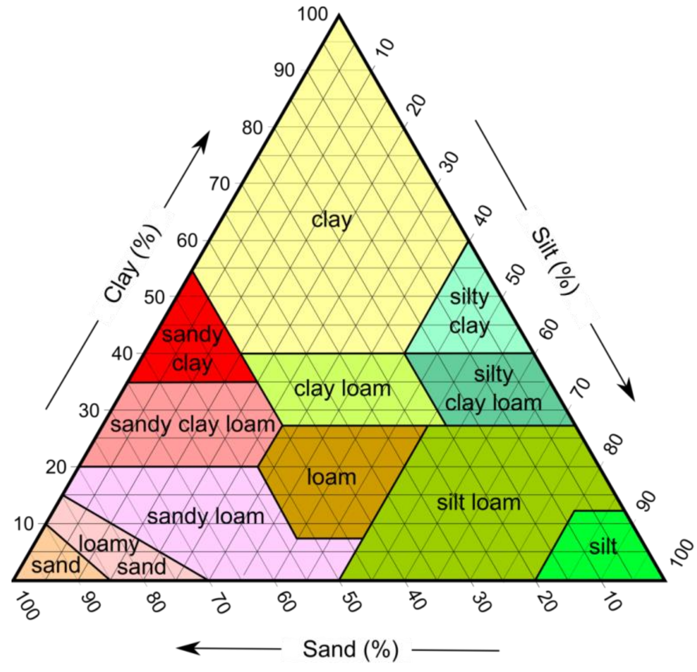


Figure 1. Soil Textural Triangle.

Air temperature

Air temperature is a measure of the kinetic energy (energy of motion) of the gases that make up the air. As gas molecules move faster, air temperature increases. In other words, air temperature describes how cold or hot the air is. Air temperature is important to understand how the atmosphere works in order to make weather predictions. For example, air temperature affects the humidity of the atmosphere, influencing the fueling of storms. Also, air temperature influences precipitation since rain, sleet, snow, or freezing rain will fall depending upon the temperature of the air.

Many biological processes are also dependent on air temperature. The metabolism in animals can slow down or increase depending upon the temperature of the environment that surrounds them. Thus, feeding, mating, migrating and other animal behaviors are partially regulated by temperature. In plants, the right temperature is needed to trigger seed germination and to promote plant growth. This indirectly affects the soil environment, for as healthy plants grow under the right environmental conditions, they develop healthy root systems on which a large variety of organisms depend.

Soil temperature

Soil temperature affects climate, plant growth, soil properties and soil processes such as rate of decomposition of organic waste. It is directly linked to the temperature of the atmosphere. Soil is an insulator for the heat that flows between the terrestrial portion of the earth and the atmosphere. During sunny days, the soil absorbs energy from the sun (radiation) and its temperature increases. During the night, the soil releases heat into the air, which affects air temperature.

Soil temperature varies through the seasons. During the summer the temperature of the soil is relatively cool, while during the winter it is relatively warm when compared to air temperature. This can influence the activities of soil organisms, indicate the right time for seed germination or the right time for animals to hibernate or emerge from the ground. For example, soil temperature becomes a limiting factor for plant growth, microbial activity, and soil respiration when it goes beyond 35 to 40 °C. While the ideal soil temperature for plants to grow ranges between 18-24 °C. However, these ranges will depend on species adaptations to local environments. Soil temperature also influences the state of water (liquid, gas, or frozen), which, combined with the amount of water in the soil, affects soil properties. Furthermore, soil temperature influences decomposition rates that can affect horizon characteristics. In cold environments, the decomposition rate is low because soil microorganisms are less active. This can result in dark-colored soils. In warm tropical climates, weathering is increased, which produces iron oxides and can result in reddish-colored soils. Lastly, soil temperature influences the evaporation of soil moisture, which affects the humidity of the air, and consequently, the climate. On the other hand, the amount of soil moisture affects the rate at which soil heats and cools. Wet soils heat slower than dry soils because the water in the pore spaces between the soil particles absorbs more heat than air in those spaces.

Soil respiration

Soil respiration is the gaseous flux of carbon dioxide (CO_2) from soils to the atmosphere. It represents one of the largest fluxes in the global carbon cycle. Soil respiration results from ecological processes such as decomposition of soil organic matter and plant litter by soil microorganisms, as well as from respiration of plant roots and soil fauna. It is an important indicator of soil health because it measures microbial activity that is critical for the conversion of nutrients into forms that plants can use.

Soils store a vast amount of organic carbon that can be released quickly or slowly into the atmosphere depending on soil respiration rates. Such rates are greatly influenced by several factors that make soil respiration very variable in space and time. Climate is a main driver of soil respiration because soil respiration increases as temperature rises, peaks under optimal soil moisture conditions, and decreases when soils are too wet or too dry. Vegetation type and phenology (timing of flowering, fruiting, and budding) also influence soil respiration through photosynthesis, because large amounts of carbon compounds from photosynthesis are allocated to plant roots and their associated symbiotic bacteria and fungi. Also, adding nitrogen to the soil promotes plant growth that consequently increases soil respiration rates.

Agriculture and other human activities (e.g. tillage, burning of fossil fuels) have a great impact on soil respiration by affecting soil factors that increase the release of soil CO_2 into the atmosphere. Consequently, soil respiration contributes to the dramatic increase of greenhouse gases in the atmosphere that are raising global temperatures affecting climate patterns.

In this protocol, you will use the Solvita ® method to measure microbial soil respiration. Microbial soil respiration is positively correlated with soil fertility and crop responses. The health of the soil microbial communities is directly associated with the amount of humus and mineralized nitrogen (the nitrogen available to plants as by-product of organic matter decomposition completed by soil microbes).

Soil water-filled pore space, water content, and bulk density

At the soil surface, carbon, nitrogen, and water can accumulate in large quantities leading to greater numbers of soil microbes and microbial activity. Aerobic microbial activity increases with soil water content until water displaces the air, restricting the availability of oxygen. At relatively high water content when aeration is not a limiting factor, microbial respiration, nitrification, and mineralization occur at maximum rates. Consequently, when soil water content reaches or exceeds field capacity, the percentage of space of soil pores filled with water is a good indicator of microbial activity. In general, maximum aerobic microbial activity is reached at 60% WFPS (Water-Filled Pore Space). Below this point, water limits microbial activity, and above 60% of WFPS, aerobic microbial activity decreases. Percent water-filled pore space (%WFPS) is determined by soil water content and soil bulk density.

Soil water content is expressed as the mass (weight) of water in a soil sample (Gravimetric water content) and as the volume of water in a known volume of soil (Volumetric water content). How much water is stored in the soil determines the soil's ability to moderate the hydrological cycle, influences weather and climate, and maintains soil-water balance. Soil moisture also influences other soil properties (color, pH, horizons) and processes. Soil processes such as soil respiration and decomposition of organic matter are influenced by soil moisture's effect on microbial activity. Soils saturated with water can be unhealthy, supporting only anaerobic microbial activity and promoting plant roots decay over time. On the other hand, in dry soils, the relatively few water molecules are strongly attached to soil particles preventing the use by soil organisms.

Soil bulk density is an indicator of soil compaction. Bulk density is the dry weight of soil for a given volume, where the volume includes the volume of particles (sand, silt, and clay) and pore space between the particles. At high bulk density, less pore space is available in the soil for oxygen, water movement, root growth, and microbe and animal activity. Bulk density can be dramatically altered by land use practices such as cultivation, trampling by stock animals, agricultural machinery, construction, and weather. Activities that compact the soil increase bulk density.

Soil fertility

Plants require *nutrients*, water, air, heat and sunlight to grow. The nutrients that plants need in large amounts are *macronutrients,* and the ones that are needed in small amounts are *micronutrients*. The fertility of the soil indicates the availability of these nutrients for the plants. Three macronutrients that are particularly important for plants to grow are nitrogen, phosphorous and potassium. These nutrients are used as parameters of soil fertility. Potassium ions are positively charged and held in the soil by negatively charged soil particles. Nitrogen and phosphorous are negatively charged and are *not* held very well by soil particles. Consequently, these two elements are easily lost from the soil due to leaching (removal from the soil as water passes through it).

Nitrogen (N) is an element found in the atmosphere in high concentrations, but in the soil, it is found in low concentrations. Nitrogen is an important component of plant proteins and nucleic acids (DNA, RNA) and promotes vegetative growth on plants. However, nitrogen cannot be used by plants in its natural form. In soil and water, inorganic nitrogen is transformed to nitrate (NO_3, the most common), nitrite (NO_2), or ammonium (NH_4), all of which are usable forms for plants. These forms of nitrogen are easily lost in the soil through leaching or evaporation. Nitrogen-fixing plants such as legumes, certain microbes, and decomposing organic matter restore nitrogen levels.

Phosphorous (P) is important in the energy pathway of plants since it is an important element in the composition of DNA and RNA. Phosphorous is available to plants in the form of phosphate (PO_4^{-3}). Phosphate can only be taken effectively up by plants when soils have a pH range of 5.0-8.0. A lack of phosphorous results in slow growth of plants, and decreased the expansion of roots. Phosphate is also easily leached from the soil.

Potassium (K) is a component of cell walls and is essential to activate cell enzymes in plants participating in the control of cellular turgor (pressure against cell walls due to the influx of water in the cell), increasing fruit size and its flavor, having a positive effect on color and fragrance of flowers, and making the plants more resistant to diseases. This element is readily available to plants, and because of its positive charge, it is easily stored in the soil.

Soil pH

pH is a parameter used to describe how acidic or basic (the opposite of acidic) a solution is. This parameter is determined by the amount of hydrogen ions (H^+) in a sample. The pH scale ranges between 1 and 14, and the lower the number the more acidic the pH of a sample is (more H+ ions). A pH around 7 is neither acidic nor alkaline, but considered to be neutral. Values of pH 8 and above are considered to be alkaline. Soils with extreme pH values may break down easier so that the soil structure and composition is not so stable. Soil acidity or alkalinity (soil pH) influences how plants grow and what kind of microorganisms may live in a soil. Soil pH is important because it determines how available nutrients may be to a plant and how easily plants can take up nutrients from the soil. Most nutrients that plants need can dissolve easily when the pH of the soil solution ranges from 6.0 to 7.5. Below pH 6.0, some nutrients, such as nitrogen, phosphorus, and potassium, are less available. When pH exceeds 7.5, iron, manganese, and phosphorus are less available. Soil pH is also an important measurement to assess the potential availability of toxic elements to plants.

With a few exceptions, most plants will tolerate a fairly wide range of soil pH. Many environmental factors, including the amount of rainfall, the vegetation type, and temperature, can affect soil pH. In general, areas with heavy rainfall and forest cover have moderately acid soils. Soils in regions with light rainfall and prairie cover, such as in parts of the Midwest, tend to be near neutral. Areas that experience a lot of drought tend to have alkaline soils. The pH of cultivated and developed soils often differs from that of the native soil because during construction of buildings, or poor farming practices, topsoil is frequently removed or lost and may be replaced by a different type of soil.

Soil active carbon

Soil organic matter (SOM) is a widely acknowledged indicator of soil health. However, it does not have a definite chemical composition. The dominant element in SOM is soil organic carbon (SOC). Soil organic carbon contains high levels of recalcitrant forms (slowly altered by microbial activity) and small portions of labile fractions (decomposing readily). The labile fraction or active carbon is the type of carbon in the SOM that is readily available to the soil microbial community as a source of energy and carbon, driving much of the biological activity in the soil and the cycling of nutrients. Active carbon has fractions of microbial biomass carbon, particulate organic matter (particles less than 2 mm and greater than 0.053 mm in size), and soil carbohydrates.

Active carbon as a soil health indicator is positively correlated with percent organic matter, aggregate stability and with soil respiration rate, a measure of biological activity in the soil. Active carbon is very sensitive to land management practices and soil productivity, responding much sooner to changes in land management practices than total organic matter.

Soil organic matter

Soil organic matter (SOM) is the organic component of soil and consists of fresh plant residues (<10 %), small living soil organisms (<5%), decomposing organic matter (active fraction; 33-50%), and stabilized organic matter (humus; 33-50%). Soil organic matter is the most important indicator of soil health and it plays many roles. It provides food for microorganisms that themselves facilitate the availability of nutrients for plants, minimizes leaching of nutrients, buffers the effects of high acidity, increases the moisture retention of the soil, the available water capacity and water filtration, helps to minimize compaction and surface crusting, holds soil aggregates together, decomposes toxic substances, and acts as a carbon sink.

The amount of organic matter in the soil ranges from less than 1% in sandy desert soils to 10-20% in forested or very poorly drained soils. In most productive agricultural soils, SOM ranges between 3-6%. In general, optimal SOM ranges between 6-8%. These numbers are going to vary by the influence of several factors on the rate of decomposition of the soil organic matter such as climate, land management, type of vegetation, texture and drainage.

Some generalities about SOM include:
- Grassland soils have higher SOM than forest soils.
- SOM increases with increasing precipitation and decreases with increasing temperature.
- Fine-textured soils have higher SOM than coarse-textured soils.
- Somewhat poorly and poorly drained soils have higher SOM than well drained soils.
- Soils in lowlands have higher SOM than soils on upland positions.

Methodology

This section presents all the information that you will need to have in order to conduct a soil health survey. It includes a detailed explanation of the sampling design (page 14-17), the equipment and materials (page 18), the protocols to measure each variable (page 25-59), and the forms where you will report the data (page 19-24).

It is very important that you become familiar with this information before you go into the field to conduct a soil health survey.

If you are not familiar with the metric system used in this manual, use the tables in Appendix 1 to convert the units of length from feet to meters and inches to centimeters, as well as the units of temperature from Fahrenheit to Celsius. The metric system is the International System of Units used by the scientific community all over the world.

WHO CAN PARTICIPATE IN THE SOIL HEALTH SURVEYS?

Volunteers across the state are invited to participate in the soil health surveys. Teenagers and adults working individually or in teams are welcome. At least one person in the team should attend a training session. *The soil health survey is not designed to be a whole classroom activity and team sizes should not exceed 5 individuals.*

SURVEY SITE SELECTION

A survey is conducted within an area of about six meters in diameter (survey site) in a site representative of a habitat. To select where to set up your survey site, you need to fulfill the requirements explained below (Figure 2). The timing of the surveys and how to collect the data are explained in following sections (page 17 and 19 respectively).

- The survey site should be in an area that is representative of a natural habitat (forest, woodland, prairie) or an anthropogenic habitat (cropland, grassland (hey field, abandoned field), animal pasture). Urban and suburban gardens are not included because are small areas that experience very intense human manipulation.
- The area of the habitat should be at least one acre in size. Exceptions may apply depending on the type of habitat.
- The survey site should be homogenous in several characteristics such as topography, elevation, habitat, soil type, etc.
- The area of the survey site should be similar in terms of management history and current management.
- The survey site should be at least 15-20 meters away from any other habitat and from water sources (ponds, lakes, and creeks), drainage, roads, trails, eroded sites, field borders, fertilizer

bands, etc. If necessary, set up your site away from visitors' sight (e.g. conservation areas and parks).
- Avoid sites that are too disturbed or that are frequently disturbed (burned (unless prescribed), flooded, eroded, logged, etc.).
- Avoid sites that are overly dry with soil filled with rocks and pebbles.
- To identify the best location for your survey site based on homogenous topography and elevation, visit the US Geological Survey website. Use the Map Locator and Downloader application to download for free a topographic map of your site ((https://viewer.nationalmap.gov/basic/?basemap=b1&category=ustopo&title=US%20Topo%20Download).
- Make sure your survey site is within the same soil map unit. Visit the SoilWeb website (http://casoilresource.lawr.ucdavis.edu/gmap/) to learn about the kind of soil in the vicinity of your survey site.
- Permission from landowners to access and work in a survey site should be granted before any measurements are taken.
- Plan to have access to the survey site once over several months of a year. Each site will be surveyed for at least one year or more. Details on the timing for sampling are explained in the section "When to conduct a soil survey" (page 17).
- Participants can monitor more than one survey site.
- If you do not have a site, you still can participate. To contact us go to page 73.

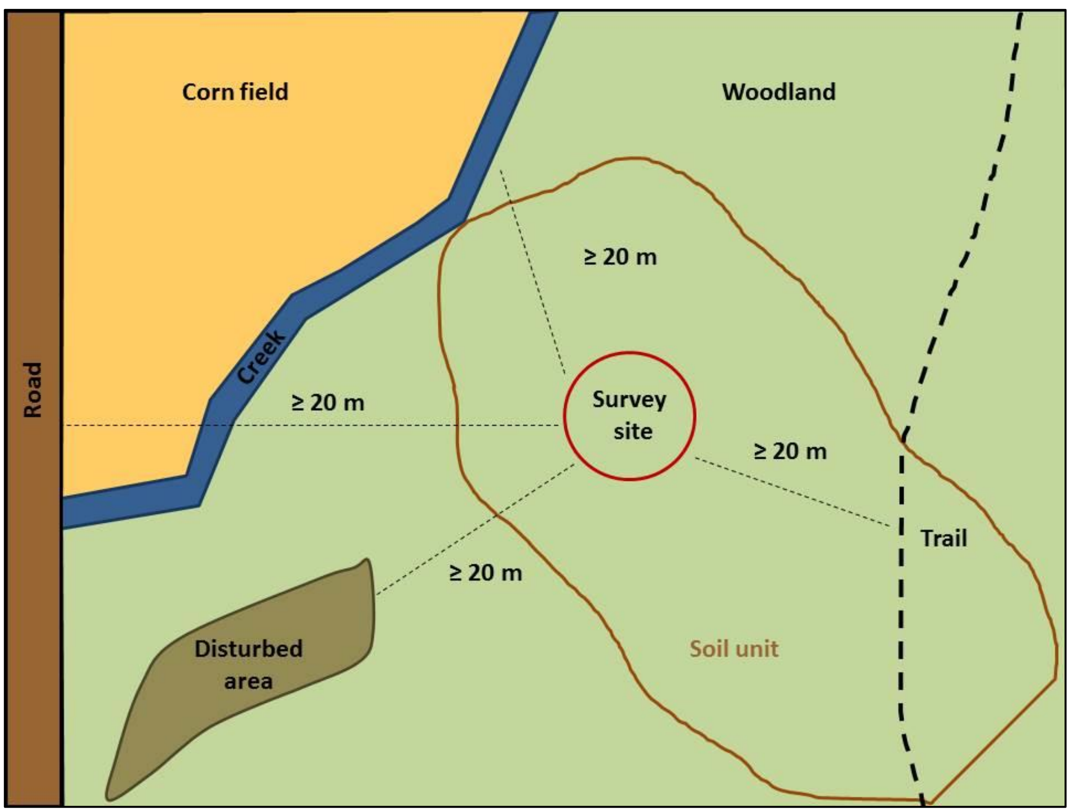


Figure 2. Hypothetical diagram of site requirements of a survey site. The survey site should be within the same habitat (e.g., woodland), at least 20 meters from water sources, trails, other habitats, disturbed areas, and within the same soil unit if possible. Diagram is not to scale.

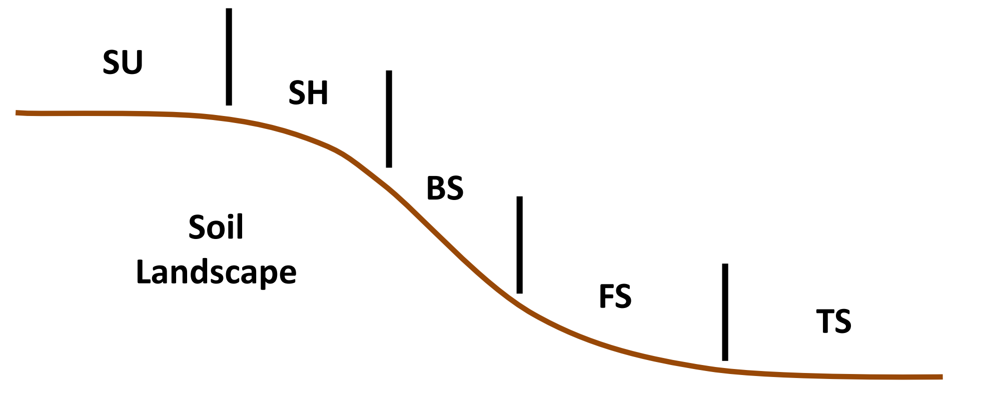


Figure 3. Hillslope cross-section depicting soil elements within the soil landscape. SU – Summit; SH – Shoulder Slope; BS – Backslope; FS – Footslope; TS – Toeslope/Floodplain.

REPLICATE SELECTION

Within a survey site, select five locations (replicates) to collect the soil data (Figure 4). These replicates should be similar among themselves. The requirements to select the replicate locations within a survey site are:

- Replicate locations should be identified within the same habitat (forest, woodland, prairie, cropland, animal pasture, grassland, etc.).
- If the replicates are on a hillslope, make sure they are all within the same element (summit, shoulder slope, backslope, footslope, or toeslope) (Figure 3). Consequently, the replicates will be similar in slope and aspect (orientation with respect to the north).
- Avoid non-representative areas within the survey site that are uncharacteristically wet or dry, extremely hilly, or eroded.
- In crop fields, select replicate locations in row areas and avoid tire tracks.

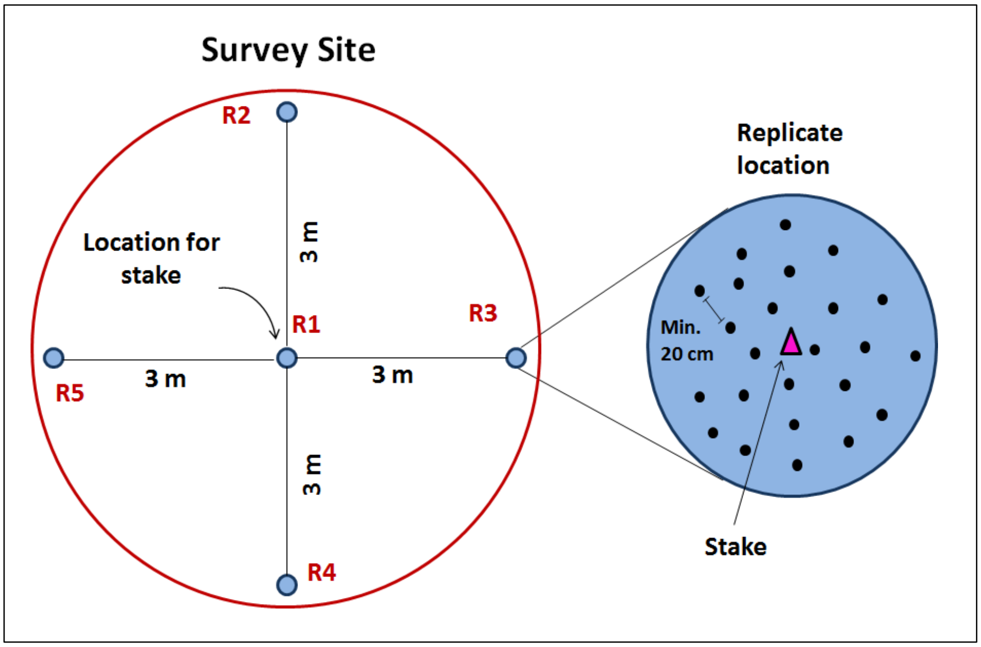


Figure 4. Hypothetical diagram of the sampling design in a soil health survey site. R1 – R5 are replicate locations. At each replicate location (big blue circle), the black dots represent soil collection sites at least 20 cm apart. These soil samples are used to measure different variables periodically. Diagram is not to scale.

HOW TO SET UP THE LOCATION OF THE REPLICATES WITHIN A SURVEY SITE

The following procedures will help you position and mark the locations of the five replicates within your survey site for the duration of the surveys (long-term monitoring) (Figure 4). You will need five stakes, marker pen, rubber mallet, measuring tape, compass, and access to GPS (Global Position System).

- At the center of the survey site, insert a stake in the soil all the way to the first mark (circle) (about 15 centimeters deep) using the rubber mallet if necessary. Use the marker pen to label the stake on its top with the replicate number 1 (R1). Record its GPS coordinates in the data sheet.
- Three meters away to the north, place another stake and label it R2.
- Go back to R1 and three meters away to the east place another stake and label it R3.
- Repeat this last step to place stakes at replicates R4 and R5 towards the south and west respectively.
- Verify with landowner that the location of the stakes will not interfere with management practices (e.g., planting, irrigation, harvesting, prescribed burning, etc.) in the long-term (year around). If there is a possibility that the stakes will be removed or damaged by such practices, record the GPS coordinates at each replicate location as accurately as possible in order to relocate locations for the next survey.
- Take a photo of your study site showing the stakes and the type of habitat.

WHEN TO CONDUCT A SOIL SURVEY

It is very important to conduct the soil surveys during the same period of time as other participating individuals or groups to give consistency and value to the data you are collecting. Below are the guidelines on *when* to conduct the surveys:

- Soil surveys are conducted once a month between February and November. Try to always do the survey during the same week per month.
- The starting month of a survey site will vary depending when a team joins the project.
- If raining, wait about 2 days to conduct the soil survey in order to give time to the soil to reach field capacity (the amount of water content held in the soil after excess water has been drained away).
- You can collect the data in the morning, noon, or afternoon, but always do all your surveys in the same period of time if possible.
- Make sure that during the time needed to collect the data there is no disturbance in the survey site. Avoid prescribed burning, planting, harvesting, etc.
- Avoid areas that have been recently disturbed due to logging or flooding.
- The timing for measuring each of the soil health indicators is explained in Table 5 (page 23).

MATERIALS AND EQUIPMENT (SOIL SURVEY KIT)

The following table lists the materials and equipment needed to conduct the soil health surveys (Table 3). Most of the items are provided by MO DIRT and some additional items are provided by the participants.

Table 3. Material and equipment provided by MO DIRT and the participants per year

MATERIAL AND EQUIPMENT PROVIDED BY MO DIRT	MATERIAL AND EQUIPMENT PROVIDED BY PARTICIPANTS
Active carbon kit ($KMnO_4$, color chart, free- standing tubes (30 ml) (2))	Camera
Auger – 10 or 12 inch length	Flat-bladed knife or pocket knife
Backpack	GPS unit (or cell phone with GPS)
Balance or scale (0.1 g precision and 400 g min. capacity)	Hot pad / oven mitt
Brush	Oven, or lamp
Clipboard with data sheets	Newspaper
Compost bowls (4)	Soap
Distilled water (1 gallon)	Watch or timer
Line level	Weight (rock)
Manual	
Measuring tape	
Metal ring	
Nail	
Nitrile gloves (1 box) (disposable)	
Permanent markers (2)	
Plastic container with lid (32 oz (946 ml)	
Plastic squeeze bulb pipette, 3 ml (2)	
Rubber mallet	
Pre-paid envelope to mail organic matter samples	
Rapitest	
Sealable bags (20)	
Set of measuring cups and spoons	
Sign “Research site”	
Soil and air thermometer	
Soil box for testing of organic matter (2)	
Soil color book	
Soil texture feel method diagram	
Solvita kit (2 jars, color chart, 10 foil pouches, notification card)	
Spatula	
Stakes (6)	
Stick	
String	
Table knife	
Tray	
Trowel	
Wooden block	

CARE OF EQUIPMENT AND MATERIALS

In the field:

- Handle the equipment carefully. Avoid putting too much pressure when inserting the stakes, thermometer, and auger in the soil.
- After collecting data in the field make sure to pick up all the items from the soil kit and place them in the backpack.

In the lab:

- Wash and clean your equipment and materials using water and hand soap (except disposable bowls), making sure they are dried before storage until the next survey.
- Metal tray: Avoid damage to the coating and pan by preventing the use of metal utensils, abrasive cleaners, and metal scouring pads. Avoid contact with salt that can cause pitting corrosion.

HOW TO COLLECT THE DATA

Information collected during the soil health surveys is recorded on a form that includes: group information, site description, and soil variables data (see form in page 64). The form has sections that are filled once a year, once a month, and twice a year (Table 5, page 23). Depending on the variable, data are collected from each of the five replicate locations, from a composite sample made of soil from each of the five replicates, or from a single sample at the center of the survey site (Replicate 1) (Table 5). Guidelines to prepare for the soil survey are also included with this form. Each of the sections of the form are explained below.

Information collected once (Pages 1 to 3 in form):

Group information:

Participants should include in the form their names, the institution they belong to, as well as the contact information of the group leader. This information is collected once during the first survey. Update this information as needed in every subsequent survey.

Survey site description:

This section includes information that describes different aspects of the survey site in terms of landscape and habitat characteristics. Update this information as needed in the following surveys.

Address: Include detailed information on how to get to the survey site.
Date: Make sure the date is recorded in this order (month/day/year).

Mean annual temperature and total annual precipitation (Normals for the period 1981-2010): This information can be found at ggweather.com/normals/MO.html. Search for the closest city/town to your survey site. For temperature look for the “Mean” row and for precipitation the “Precip” row, both in the last columns. The values for temperature are in Fahrenheit degrees and the values for precipitation are in inches. To convert these values to Celsius degrees and millimeters, use the tables in Appendices 1 and 2, or use an on-line conversion site for temperature and length.

Elevation: Is the height above sea level of a location and should be recorded in meters at the center of your survey site (Replicate 1 (R1)). Use any elevation finder in the web to search by address or coordinates (e.g. www.distancesto.com/elevation.php, www.freemaptools.com/elevation-finder.htm).

Slope: To estimate the slope (Figure 5), insert a stick in the soil at the highest point of the sampling area. Attach a string at the base of the stick. Hold the string horizontally, using the line level, towards the base of the slope. The leftover string will fall on the ground. Attach a weight to the string to form a solid 90° angle. Measure the length of string from the high point to your hand. Then, measure the height from the string in your hand to the ground. To find the percentage of slope, simply divide the rise (the measured height) by the run (the measured length) and multiply by 100. If your site is flat, the slope is 0%.

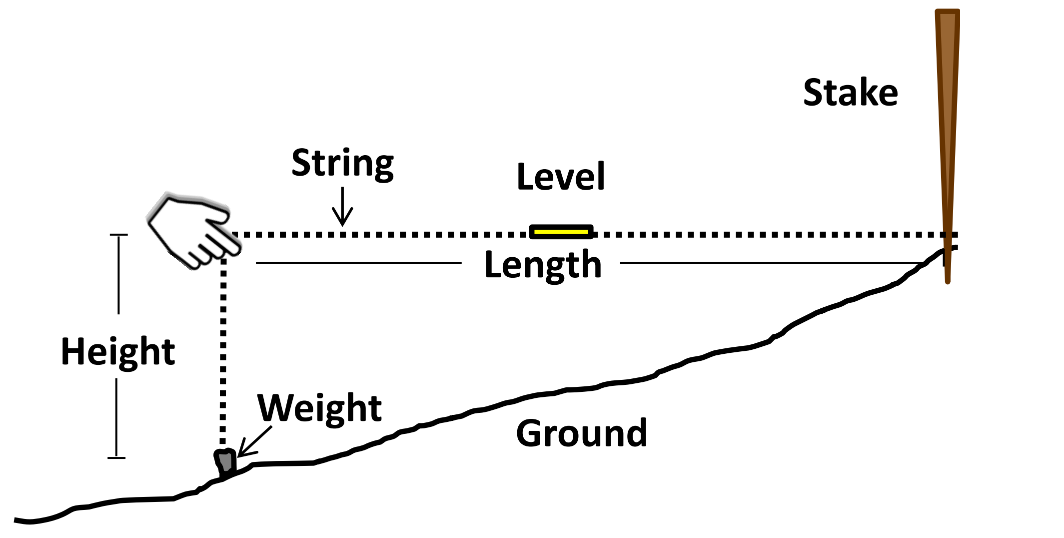


Figure 5. How to measure a slope.

Aspect: If your survey site is on a slope, record the approximate position of the site with respect to the points of the compass (i.e., N-north, S-south, E-east, W-west, NE-northeast, NW-northwest, SE-southeast, SW-southwest). Write N/A (not applicable) when your site is flat.

Latitude and longitude: Record the geographical coordinates in decimal degrees at the replicate location 1 (R1) (e.g. 37.715930, -92.135860). To find the coordinates, use any Map App in your phone or the SoilWeb website that is explained in the next page under “Soil map unit name and symbol”. If your coordinates are given in degrees, minutes, and seconds (e.g.

37°51’21” N 90°18’08”W), convert them to decimal degrees using the following website: http://andrew.hedges.name/experiments/convert_lat_long/. If the stakes cannot be used to mark the replicate locations, record the coordinates at each replicate location to relocate them during the next survey.

Habitat type: Include the type of habitat where your survey site is [e.g., forest, woodland, prairie, grassland (hay field, abandoned field), cropland (tillage, no-tillage) or animal pasture]. Include additional information to describe the crop system if applicable. Use the habitat guide to confirm that your survey site is assigned to the correct habitat type. Access the guide at modirt.missouriepscor.org/sites/default/files/files/Habitat%20Guide.pdf.

Photo of habitat: Take a photo of the habitat of your survey site and send the image to modirt@danforthcenter.org.

Topography: Report the presence of topographical features (e.g., hills, ridges, depressions, knolls, potholes, etc.).

Soil map unit name and symbol: A soil map unit is a collection of areas named the same in terms of their soil components. To find the map unit of your site, visit the SoilWeb website (casoilresource.lawr.ucdavis.edu/gmap/). You will see contour yellow lines that delineate soil map units label with five digit numbers (symbols). 1) Go to “Menu” and select “Zoom To Location” and enter the address or coordinates of your survey site. Zoom in as necessary until you find the location of your survey site. 2) Click on your survey site location and a window will appear on the top left of the screen with the soil map unit name and symbol on the top, as well as additional map unit data (e.g. Lily-Hobson-Ramsey complex, 8 to 15 percent slopes (73589)). You can download the SoilWeb App to your phone at casoilresource.lawr.ucdavis.edu/soilweb-apps/. The coordinates are shown as you move the cursor on the bottom right of the screen.

Survey site landscape position: Look at the diagram in page 16 to identify the position of the survey site in the landscape (e.g., summit, shoulder slope, backslope, footslope, toeslope/floodplain) (Figure 3).

Present land management: Record the current activities that are taking place in the survey site by contacting the landowner (e.g., logging, reforestation, flooding, pesticides, fertilizers, irrigation, prescribed burns, undisturbed, etc.).

Past management system: Record the past activities that took place in the survey site by contacting the landowner (e.g., logging, reforestation, flooding, pesticides, fertilizers, irrigation, prescribed burns, undisturbed, unusual events (floods, fires, land leveling, etc.)).

Soil color: With a soil sampler, soil is collected from the center of the survey site (Replicate 1) to determine the soil color at different layers (Table 5 page 23, Protocol page 26).

Soil texture: With a soil sampler, soil is collected from the center of the survey site (Replicate 1) to determine the soil texture at different layers (Table 5 page 23, Protocol page 29).

Drawing of the site: Make a drawing that includes the approximate location of the replicate samples and their surroundings, including landmarks or other features of relevance. Take a photo of your drawing to upload in the data portal (optional).

Information collected once a month (Table 5 page 23) (Pages 4 to 6 in form):

Provide participant’s names, as well as updated contact information and site description if necessary.

% Cloud cover: This is an estimate of the percentage of visible sky that is covered with clouds at the moment of sampling and is an indication of the weather conditions at the moment. Use the cloud cover chart in Table 4 to make the estimate.

Table 4. Cloud cover chart

CLOUD COVER CLASSIFICATIONS
No Clouds The sky is cloudless; there are no clouds visible.
Clear Clouds are present but cover less than one-tenth (or 10%) of the sky.
Isolated Clouds Clouds cover between one-tenth (10%) and one-fourth (25%) of the sky.
Scattered Clouds Clouds cover between one-fourth (25%) and one-half (50%) of the sky.
Broken Clouds Clouds cover between one-half (50%) and nine-tenths (90%) of the sky.
Overcast Clouds cover more than nine-tenths (90%) of the sky.
Obscured Clouds cannot be observed because more than one-fourth (25%) of the sky cannot be seen clearly. If the sky is obscured, record what is blocking your view of the sky (e.g., fog, smoke, haze, volcanic ash, dust, sand, heavy rain, etc.).

Air temperature: Measure this variable in Celsius degrees (°C) at 1.5 m in the air at each replicate location (Protocol page 34).
Soil temperature: Measure this variable in Celsius degrees at surface level (0 cm), 5 cm, and 10 cm depth at each of the replicate locations (Protocol page 35).
Soil respiration: Use a Solvita kit to record color change over time from a paddle in a jar with a soil sample to interpret CO_2 emissions (Protocol page 39). The soil sample is a composite sample made of soil from each of the five replicate locations.
Soil bulk density, water content, and water-filled pore space: Calculate the density of dry soil in a known volume and the amount of water from a composite soil sample (Protocol page 43).

Information collected twice a year (Table 5 page 23) (Page 7 in form):

Soil nutrients: Use the Rapitest kit to estimate the content of nitrogen, phosphorous and potassium in a soil sample (Protocol page 50). The soil sample is a composite sample made of soil from each of the five replicate locations.
pH: Use the Rapitest kit to estimate the pH of a soil sample (Protocol page 53). The soil sample is a composite sample made of soil from each of the five replicate locations.

Active carbon: Use a potassium permanganate test to estimate the amount of active carbon in a soil sample (Protocol page 55). The soil sample is a composite sample made of soil from each of the five replicate locations.
Soil organic matter: A soil sample, from a composite sample made of soil from each of the five replicate locations, is sent to a soil testing lab to estimate the percentage of organic matter in the sample (Protocol page 58).

Table 5. Timeline of the variables measured in a soil health survey over time with the number of replicates and readings per variable per survey

No. of replicates	No. of readings per variable	Variables	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Once a year measurements												
1	1	Soil color [a]	Measured at any survey									
1	1	Soil texture [a]	Measured at any survey									
Monthly measurements												
1	1	% cloud cover [b]	x	x	x	x	x	x	x	x	x	x
5	5	Air temperature [b]	x	x	x	x	x	x	x	x	x	x
5	5	Soil temperature	x	x	x	x	x	x	x	x	x	x
5	1 [c]	Soil respiration	x	x	x	x	x	x	x	x	x	x
5	1 [c]	Soil water content	x	x	x	x	x	x	x	x	x	x
1	1	Bulk density [d]	Measured during the first survey									
1	1	Water-filled pore space [e]	x	x	x	x	x	x	x	x	x	x
Twice a year measurements [f]												
5	1 [c]	Soil fertility (N, P , K)				x			x			
5	1 [c]	pH				x			x			
5	1 [c]	Active carbon				x			x			
5	1 [c]	Soil organic matter				x			x			

[a] It is recommended that these measurements be taken at the beginning of the project.
[b] % cloud cover and air temperature are part of the site description, not soil health indicators.
[c] Measurement from a composite soil sample obtained from soil collected in the five replicates.
[d] Although it is a variable that is measured once a year, its value is used to calculate water-filled pore space on a monthly basis.
[e] Soil water content and bulk density are used to calculate water-filled pore space.
[f] Twice a year measurements are collected in May and August if your site experiences major disturbances (e.g. flooding, burning, logging, crop and pasture management, etc.). These measurements can be collected once in either May or August, if your site does not experience major disturbance (e.g. forest, woodland, abandoned grassland).

Considerations to follow when you collect the data and record it in the data sheets

Check in advance that the instruments you are going to use are calibrated and work properly.
Become familiar with the equipment, including the meaning and interpretation of their readings.
Be patient and wait until the readings in an instrument stabilize in order to collect data accurately.
Make sure you position the instruments at the right depths.
Make sure to write the data in the correct cells and in the right units.
Consider when you record the data, that an empty cell is different from a zero value. When you do not have data for a cell, explain the reason in the "notes" section.
After you collect the data, look through the values to see if you spot mistakes, for example missing values, missing periods in decimal numbers, extra zeros, etc.

Each variable has a protocol that is described in the next section. Each protocol includes background information, materials, sampling guidelines and the measurement procedures.

WHAT TO DO WITH THE DATA

Data entry

The data you collect every month should be kept in a safe place. If possible, make photocopies or take photos of your data and keep them in a separate place than the originals. As soon as possible, enter the data on-line. You can find the instructions in the Data Portal Manual you should have received at the training. You can access the manual on-line at: http://modirt.missouriepscor.org/sites/default/files/files/Manual%20data%20entry%20on-line(2).pdf.

Data sharing

When you create your account to enter the data on-line, you will have the option to share the data with the general public, among the MO DIRT participants, or only with the EPSCoR scientists.

Data search

MO DIRT has a Data Search Portal where the soil health surveys can be search based on habitat type, location, and variable sets (http://modirt.missouriepscor.org/soilhealthsurveys/search-data). The data can be exported.

PHOTOS

Take photos of your study site and you and other members of your team conducting the soil health survey. Send the images to modirt@danforthcenter.org.

PROTOCOLS FOR VARIABLES COLLECTED ONCE

SOIL COLOR PROTOCOL

Background

Soil color is an indicator of various chemical processes acting on soil. These processes include the weathering of geologic material, the oxidation-reduction reactions on soil minerals (mainly iron and manganese), and the decomposition of organic matter. Climate, physical geography, and geology influence these processes.

Soil color can be used to estimate the organic matter content of the soil, to indicate the effects of human disturbance and past vegetation, to identify, classify and evaluate soils, and to locate where the soil water table is, among many other soil activities.

There are two primary coloring agents in soil: organic matter and iron. Dark surface soil usually indicates high content of organic material, while shades of red, yellow, and gray usually relate to the quantity and form of iron present.

Color development and distribution of color within a soil profile are part of weathering. Also, as organic matter decomposes into black humus, it coats surfaces of soil as it permeates through the soil. Humus color decreases with depth, and iron pigments become more apparent. So, as depth below the surface soil increases, colors become lighter, yellower, or redder. See Table 1 below for the interpretation of soil colors.

The Munsell System of Color Notation (www.munsell.com) is a system used to compare soil colors anywhere in the world. This system helps scientists to be consistent in the interpretation of colors. It has three components: hue (specific color), value (lightness and darkness), and chroma (color intensity) that are arranged in books of color chips. Soil samples are held next to the chips to find a visual match and assigned the corresponding Munsell notation. For example, a brown soil may be classified as: hue value/chroma (10YR 5/3).

Materials

- Auger
- Clipboard and data Sheet
- Distilled water
- Permanent marker
- Plastic squeeze bulb pipette
- Rubber mallet
- Soil color book
- Soil sample

Soil color identification

Table 1. General interpretation of soil colors

SOIL COLOR	DUE TO THE PRESENCE OF:	COMMENTS
Dark or black	Organic matter	Mostly found at soil surfaces. Associated with well-aggregated soils with above-average nutrient levels.
Clear or white	Calcium and magnesium carbonates, soluble salts or high proportion of sand (quartz crystals)	May indicate considerable leaching and low organic matter.
Red and bright yellowish	Iron is oxidized and not hydrated with water	Under dry conditions or well-drained soils. The iron oxides have strong surface charge properties that promote good aggregation of soil particles with sufficient porous that allow air and water for root development.
Yellowish brown/orange	Less oxidation of iron and hydration	Average air and moisture conditions.
Mucky soil mass or clay with spots of red, yellow, and gray colors	Ferrous and ferric compounds	In soils that are waterlogged for at least one part of the year, or due to the activity of plant roots living in ponding.
Grey/green/bluish-grey	Iron and manganese in reduced state	In waterlogged soils with lack of oxygen with colorless forms due to the loss of pigments.

Sampling guidelines

- Soil color is determined at a single location at the center of the sampling site (R1).
- Readings of soil color are taken from a single soil sample obtained with an auger of up to 10” depth.
- Determine soil color at each layer (horizon) found along the soil core in the auger if they differ.
- With the same soil sample obtained from the auger, readings of soil texture are taken (next protocol).
- Never sample twice from the same spot within a period of several years.
- Soil color readings are taken once at the beginning of the project.
- Two participants can do the sampling and processing for this indicator.

Measurement procedures

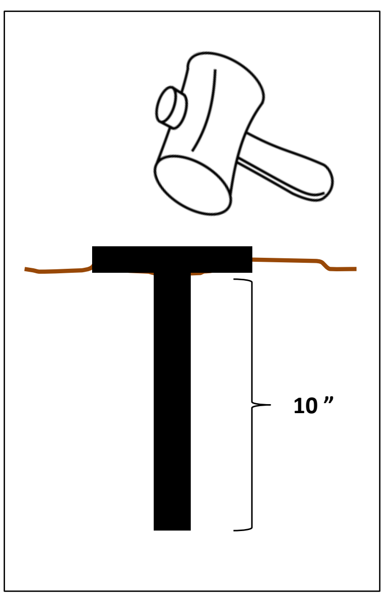
How to take the soil sample:

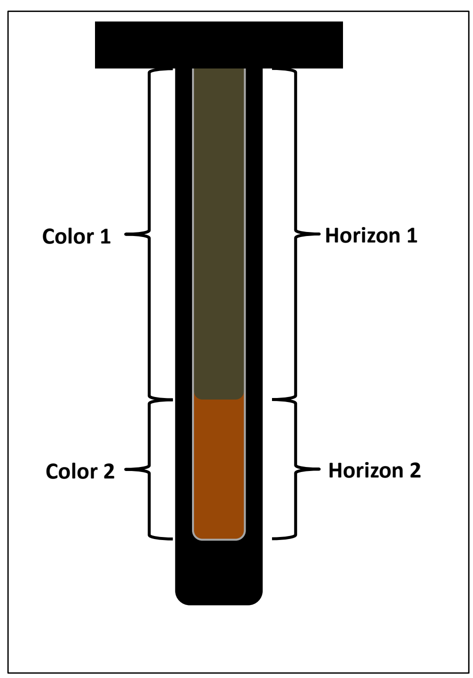
1. Identify a location at the center of the sampling site (R1).
2. Insert the auger in the soil all the way down by turning the sampler to dig into the ground. Use the rubber mallet to push the auger if needed.
3. **If you find it difficult to insert the auger** in the soil due to presence of gravel or rocks, **do not force it** and take the sample **only** to the depth you can.
4. Pull the auger out of the soil with the soil sample.
5. Identify differences in soil color along the sample core. The areas with different colors are layers or soil horizons. Look for flecks or patches of color as well.
6. In the data sheet, you can include information for up to four layers, but if you find more, add this additional information in the "Notes" section.

How to take the soil color readings:

1. For each layer, assign a soil color using the soil color book.
2. Take a ped (soil aggregate) from the layer with your fingers and note whether it is moist, dry, or wet. If it is dry, moisten it slightly with water using a plastic squeeze bulb pipette.
3. Break the ped and hold it next to the color chart. Stand with the sun over your shoulder so that sunlight shines on the color chart and the soil sample you are examining.
4. Find the color in the color book that most closely matches the color of the inside surface of the ped. Be sure that all group participants agree on the choice of color.
5. Record the chosen color in the data sheet.

Use this same soil sample to determine the soil texture (See protocol in page 29).





SOIL TEXTURE PROTOCOL

Background

Soil texture is described by the presence and relative proportions of the three types of particles that make up soil: sand, silt, and clay. These particles differ in size as follows (Table 2):

Table 2. Soil particle classification according to the International Society of Soil Science

Diameter of the particles (mm)	Classification
> 2	Stony structure
2 – 0.2	Coarse sand
0.2 – 0.02	Fine sand
0.02 – 0.002	Silt
<0.002	Clay

Particles classification according to the International Society of Soil Science

Depending on their texture, soils will vary in their ability to retain water and nutrients. A simple way to examine soil texture is to physically handle dry and wet soil samples, using your fingers to work with small soil samples. *Sandy soils* feel rough (gritty) because sand particles have hard edges. These soils do not hold many nutrients because they have large pores that allow gases and water to move through them rapidly. The *sand* particles do not adhere to each other and cannot stay together. *Silty soils* are smooth and powdery, and when wet, they make crumbles or ribbons, but are not sticky. Silty soils have smaller pore spaces than sandy soils, therefore, they can hold more water. *Clayey soils* are smooth when dry and sticky when wet, making balls or ribbons that stay together. Because their particles are so small, clayey soils can hold large quantities of nutrients, water, and gases.

Most soils contain different combinations of sand, silt, and clay. The Soil Textural Triangle (Figure 1) shows the twelve possible soil classes based on the relative percentages of these combinations of textures. The most appropriate soil class for plant growth is loam, which can absorb water very efficiently. The loam soil is composed of mostly sand and silt, with a smaller amount of clay.

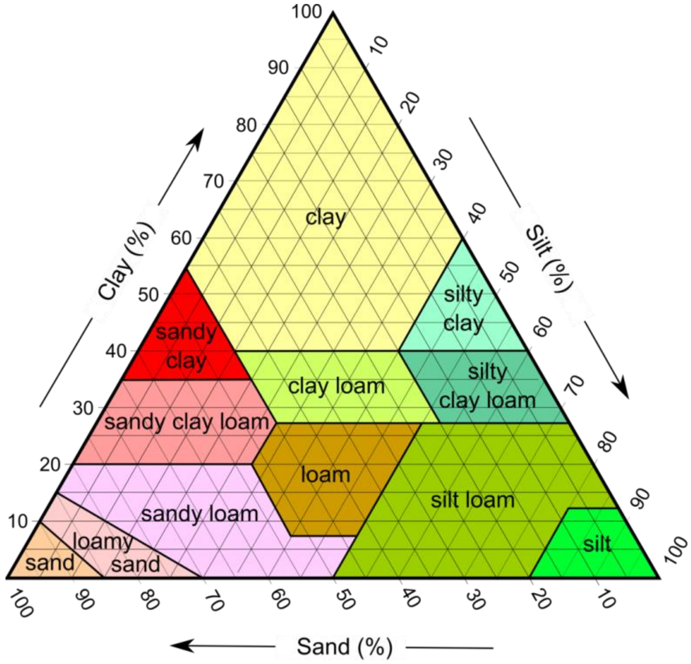


Figure 1. Soil Textural Triangle.

Materials

Collecting a soil core with the auger

- Auger
- Brush
- Clipboard and data sheet
- Distilled water
- Permanent marker
- Plastic squeeze bulb pipette
- Rubber mallet
- Soil texture feel-method diagram
- Stick
- Table knife

Sampling guidelines

- Soil texture is determined at the center of the sampling site (R1).
- Readings of soil texture are from a single soil sample obtained with an auger to 10 inches depth.
- With the same soil sample obtained from the auger, readings of soil color are taken.
- Determined soil texture at each layer (horizon) found along the soil core in the auger.
- Never sample twice from the same spot within a period of several years.
- Soil texture readings are taken once at the beginning of the project.
- Two participants can do the sampling and processing for this indicator.

Measurement procedures

How to take the soil sample:

1. Use the same sample used with the soil color protocol (Page 26).

How to take the soil texture reading:

2. Use the feel-test method to determine the texture of each of the soil layers you found in the soil core. Use the flow diagram in the next page (Figure 7).
3. Record the information on the data sheet.
4. In the data sheet, you can include information about up to four layers, but if you find more, add the additional information in the "Notes" section.

Cleaning: Remove the soil inside the auger with the table knife and the brush. Wash with mild soap and water and let it dry.

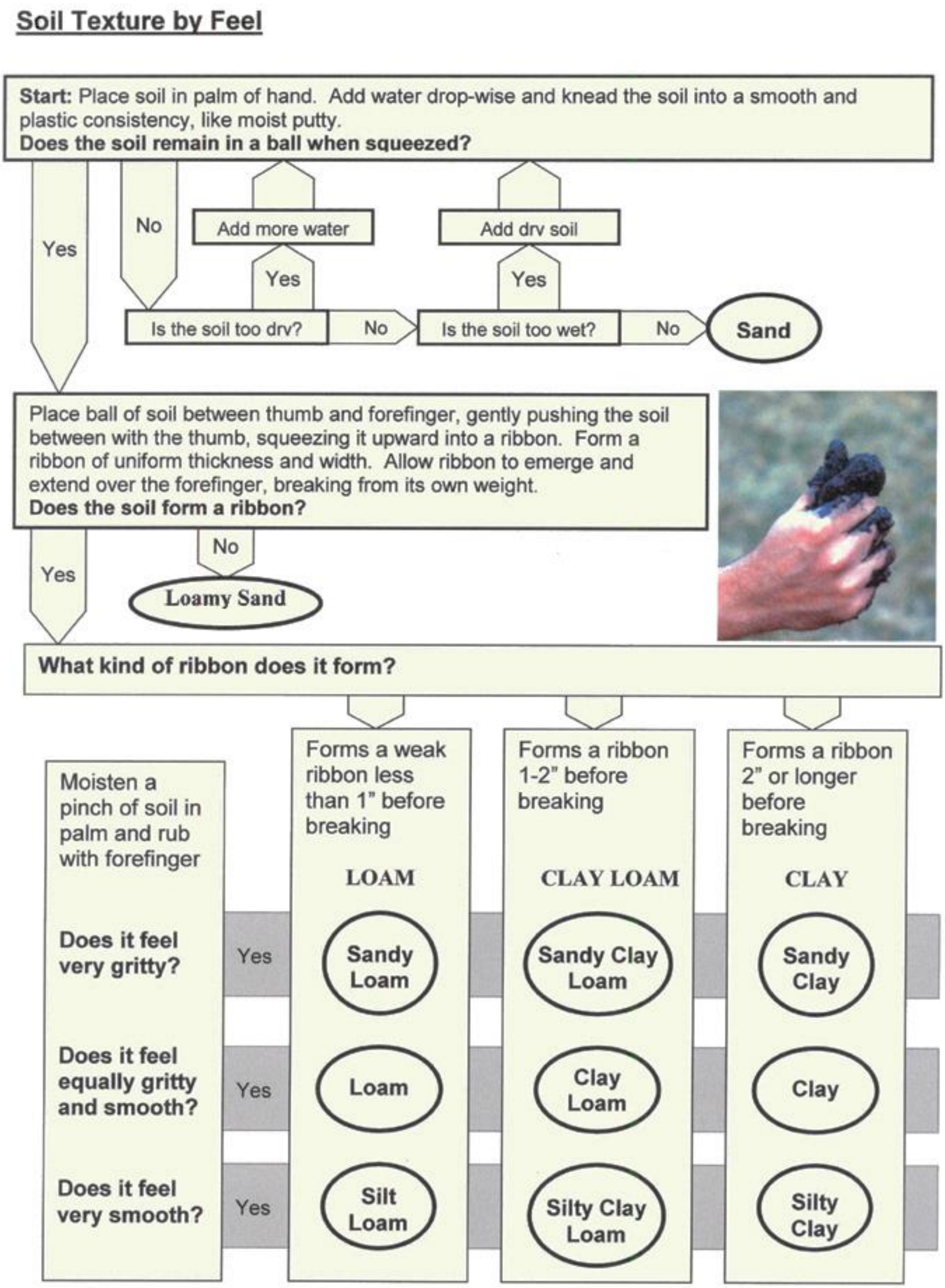


Figure 7. Diagram of the steps to conduct the feel method to determine the texture of a soil sample. Source: CMG GardenNotes #214, Colorado State University.

PROTOCOLS FOR VARIABLES TO MEASURE EACH MONTH (FEBRUARY TO NOVEMBER)

AIR TEMPERATURE PROTOCOL

Background

Air temperature is a measure of the kinetic energy (energy of motion) of the gases that make up the air. As gas molecules move faster, air temperature increases. In other words, air temperature describes how cold or hot the air is. Air temperature is important to understand how the atmosphere works in order to make weather predictions. For example, air temperature affects the humidity of the atmosphere, influencing the fueling of storms. Also, air temperature influences precipitation since rain, sleet, snow, or freezing rain will fall depending upon the temperature of the air.

Many biological processes are also dependent on air temperature. The metabolism in animals can slow down or increase depending upon the temperature of the environment that surrounds them. Thus, feeding, mating, migrating and other animal behaviors are partially regulated by temperature. In plants, the right temperature is needed to trigger seed germination and to promote plant growth. This indirectly affects the soil environment, for as healthy plants grow under the right environmental conditions, they develop healthy root systems on which a large variety of organisms depend.

Materials

- Clipboard and data sheet
- Measuring tape
- Permanent marker
- Thermometer (the same to measure soil temperature)
- Watch or timer

Sampling guidelines

- An air reading is taken at each replicate location.
- Air readings are taken once a month in Celsius degrees.
- Make sure the thermometer is positioned at the correct height.

Measurement procedures

1. Calibrate the thermometer following the instructions that are in the box.
2. At Replicate 1 (R1) use the measuring tape to determine the height at which you will measure air temperature (1.5 m).
3. Hold the thermometer at this height and wait until the sensor gives a stable reading (~2 minutes).
4. Record the reading on the data sheet.
5. Repeat steps 1-3 at each of the remaining replicate locations (R2-R5).

SOIL TEMPERATURE PROTOCOL

Background

Soil temperature affects climate, plant growth, soil properties and soil processes such as rate of decomposition of organic waste. It is directly linked to the temperature of the atmosphere. Soil is an insulator for the heat that flows between the terrestrial portion of the earth and the atmosphere. During sunny days, the soil absorbs energy from the sun (radiation) and its temperature increases. During the night, the soil releases heat into the air, which affects air temperature.

Soil temperature varies through the seasons. During the summer the temperature of the soil is relatively cool, while during the winter it is relatively warm when compared to air temperature. This can influence the activities of soil organisms, indicate the right time for seed germination or the right time for animals to hibernate or emerge from the ground. For example, soil temperature becomes a limiting factor for plant growth, microbial activity, and soil respiration when it goes beyond 35 to 40 °C. While the ideal soil temperature for plants to grow ranges between 18-24 °C. However, these ranges will depend on species adaptations to local environments.

Soil temperature also influences the state of water (liquid, gas, or frozen), which, combined with the amount of water in the soil, affects soil properties. Furthermore, soil temperature influences decomposition rates that can affect horizon characteristics. In cold environments, the decomposition rate is low because soil microorganisms are less active. This can result in dark-colored soils. In warm tropical climates, weathering is increased, which produces iron oxides and can result in reddish-colored soils.

Lastly, soil temperature influences the evaporation of soil moisture, which affects the humidity of the air, and consequently, the climate. On the other hand, the amount of soil moisture affects the rate at which soil heats and cools. Wet soils heat slower than dry soils because the water in the pore spaces between the soil particles absorbs more heat than air in those spaces.

Materials

- Brush
- Clipboard and data sheet
- Nail
- Permanent marker
- Soil thermometer
- Watch or timer

Soil thermometer at 5 cm depth.

Sampling guidelines

- Soil readings at three depths (0 cm, 5 cm, and 10 cm) at each replicate location.
- Soil readings are taken once a month in Celsius degrees.
- The collection of soil samples for soil moisture can be collected while sampling soil temperature.

Measurement procedures

1. Calibrate the thermometer following the instructions that are in the box.
2. Use the marker to make a line around the probe at 5 and 10 cm. Measure the distances from the tip towards the top of the thermometer.
3. At Replicate 1 (R1), position the tip of the thermometer at the interface between soil and vegetation/leaf litter (if there is any). Wait until the sensor gives a stable reading (~2 minutes) and record the temperature in the data sheet (surface temperature/0 cm).
4. At R1, remove leaf litter or other debris and insert the thermometer up to 5 cm into the soil and wait until the sensor gives a stable reading (~2 minutes). If you cannot insert the thermometer to the desired depth try again at a different spot a few centimeters away or use a nail to make a hole to place the thermometer. Avoid moving the nail to the sides, as this generates air pockets that alter the temperature reading. Record the reading in the data sheet.
5. After taking the second reading, push the thermometer to a depth of 10 cm. Wait for the sensor to stabilize (~2 minutes) and record the third reading in the data sheet. If there is difficulty in inserting the thermometer, try the options mentioned earlier.
6. Repeat steps 2-4 at each of the remaining replicate locations (R2-R5).
7. Clean the thermometer with a cloth or a brush to remove attached soil.

COMPOSITE SOIL SAMPLE COLLECTION PROTOCOL TO MEASURE SOIL RESPIRATION, NUTRIENTS, PH, AND ACTIVE CARBON

This protocol refers to the collection of a composite sample made of soil subsamples from the five replicate locations. This composite sample is used to test the following variables: soil respiration, water content, nitrogen, phosphorous, potassium, pH, active carbon, and organic matter.

Materials

- Brush
- Nitrile gloves
- Permanent marker
- Sealable bag
- Tray
- Trowel

Sampling guidelines

- The soil sample in this protocol is a combination of soil subsamples from each of the five replicates.
- There is one value per variable instead of five per sampling period.
- The samples are taken from the top 7 cm of the soil once a month.
- The composite soil sample will be used to calculate once a month soil respiration as well as water content (except the month when bulk density is measured) (see page 44), and only twice a year (May and August) to calculate the other variables.
- Never sample twice from the same spot within a period of several years.
- Switch sampling location within a 1 meter radius at each replicate site.
- Two or more participants can do the soil collection in the replicate locations.

Sampling procedures

In the field:

1. Remove vegetation/leaf litter from where you will collect the soil sample.
2. Wear gloves to avoid touching the soil with your hands. This will prevent contamination for future measurements.
3. Use a trowel to collect one cup of soil up to 5 cm deep from each of the five replicate locations. Remove rocks, animals, roots and other big items that are not soil.
4. Place the five soil samples (total of 5 cupfuls) in the same sealable bag and seal it tightly.
5. Label the bag with the site name, date, and title “Composite sample”.
6. Return to the lab as soon as you can to analyze the soil sample.

In the lab:

1. Keep the bag sealed and mix the sample in the bag by kneading it with the fingers.
2. Place the soil sample in a tray and, using gloves, remove plant matter, leaf litter, any fauna and rocks.
3. Work quickly to avoid losing significant soil moisture.
4. Use the composite sample, in the months of May and August, to perform each of the analyses for soil respiration, water content, soil nutrients (N, P, K), pH, active carbon, and organic matter following the respective protocols for each indicator.
5. After finishing with all tests, wash the trowel, tray, bags, etc. with warm water and soap and let them dry.
6. Clean the work area.

SOIL RESPIRATION PROTOCOL

Background

Soil respiration is the gaseous flux of carbon dioxide (CO_2) from soils to the atmosphere. It represents one of the largest fluxes in the global carbon cycle. Soil respiration results from ecological processes such as decomposition of soil organic matter and plant litter by soil microorganisms, as well as from respiration of plant roots and soil fauna. It is an important indicator of soil health because it measures microbial activity that is critical for the conversion of nutrients into forms that plants can use.

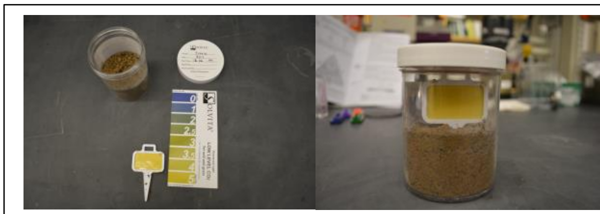
Soils store a vast amount of organic carbon that can be released quickly or slowly into the atmosphere depending on soil respiration rates. Such rates are greatly influenced by several factors that make soil respiration very variable in space and time. Climate is a main driver of soil respiration because soil respiration increases as temperature rises, peaks under optimal soil moisture conditions, and decreases when soils are too wet or too dry. Vegetation type and phenology (timing of flowering, fruiting, and budding) also influence soil respiration through photosynthesis, because large amounts of carbon compounds from photosynthesis are allocated to plant roots and their associated symbiotic bacteria and fungi. Also, adding nitrogen to the soil promotes plant growth that consequently increases soil respiration rates.

Agriculture and other human activities (e.g. tillage, burning of fossil fuels) have a great impact on soil respiration by affecting soil factors that increase the release of soil CO_2 into the atmosphere. Consequently, soil respiration contributes to the dramatic increase of greenhouse gases in the atmosphere that are raising global temperatures affecting climate patterns.

In this protocol, you will use the Solvita ® method to measure microbial soil respiration. Microbial soil respiration is positively correlated with soil fertility and crop responses. The health of the soil microbial communities is directly associated with the amount of humus and mineralized nitrogen (the nitrogen available to plants as a by-product of organic matter decomposition completed by soil microbes).

Materials

- Balance or scale (0.1 grams precision and 400 grams minimum capacity)
- Brush
- Clipboard and data sheet
- Composite soil sample
- Distilled water
- Nitrile gloves
- Permanent marker
- Plastic squeeze bulb pipette
- Sealable bag



Solvita soil kit and set up for measuring soil respiration

- Solvita kit (1 jar with lid, foil pouch with paddle, color chart). Keep the Solvita foil pouches in a cool place or in a refrigerator (must not be allowed to freeze) away from sunlight to prevent changes in temperature. Allow pouches to adjust to room temperature before use.
- Tray
- Watch

Sampling guidelines

- The soil used in this protocol is from a fresh composite soil sample. See protocol in page 37.
- The samples are taken from the top 7 cm of the soil.
- There is one value for this variable (instead of five) per sampling.

Measurement procedures – See video at modirt.missouriepscor.org/node/304

In the lab:

1. Using gloves, place a portion of the fresh composite soil sample on the tray (~ 1 cup). Clean the soil sample as much as you can of roots and any other organic material. Keep the rest of the composite soil sample in the sealable bag and keep the bag closed.
2. Place the Solvita jar on the balance and zero-out the weight of the jar.
3. Fill the Solvita® jar with the soil, using the fill line as a guide until it weighs 90 g.
4. Tap the bottom of the jar on a hard surface occasionally during filling to eliminate voids or air pockets.
5. Open the foil pouch and insert the gel paddle into the soil with the gel facing the clear side of the jar. Be careful not to jostle or tip jar. The soil should not touch the gel in the paddle.
6. Screw the lid on tightly and let the jar stand undisturbed for 24 hours, and keep it in a room with a controlled temperature of 20 °C - 22 °C (68 °F - 72 °F), away from sunlight.
7. Record in the data sheet the start time of the experiment and the color in the paddle at 0, 1, 2, 3, 4, 5, 10, and 24 hours into the experiment. Use the color chart to determine the number for the color on the paddle. Note that the color on the paddle may not exactly match any of the colors on the chart. Select the best match. The color chart indicates to “Use under fluorescent light”. However, if you do not have access to this type of light, you can use the day light to determine the color.
8. Do not delay the reading of the gel paddle because the color changes over time with CO_2 release from the soil.
9. Dispose of the soil leftovers after setting up the experiment.
10. At the end of the experiment, clean the jars with mild soap and water and dispose of the paddles.

Data interpretation

Use Table 6 to translate the colors and numbers in the paddle and color chart to biological soil conditions, and emissions of carbon in carbon dioxide (CO_2-C) or carbon dioxide (CO_2) to the atmosphere in cultivated soils. If your survey is in a natural habitat (e.g., forest, woodland, prairie), you may have to do an additional step as explained next.

Cultivated soils

Data interpretation in Table 6 is based on soil samples from moist cultivated soils tested at room temperature of 20 °C - 22 °C (68 °F - 72 °F) after 24 hours into the test.

Soils from natural habitats

Soils from some natural habitats might be "fast risers" which means they are associated with high-functioning systems with high levels of organic matter and microbial rates. This might be reflected in a fast change in paddle colors.

1. Identify your soil as a "fast riser" if it has reached a color number of 5 or 6 by five hours into the experiment.
2. Continue recording the color change until it reaches the number 6.
3. If your soil is a "fast riser", take the color reading at 5 hours and find the respective amount of CO_2-C lbs/acre/day in Table 6. The table will give you a range of numbers for a particular color.
4. Multiply both numbers in the range by 2.5, the conversion factor to estimate the equivalent numbers after 24 hours. Write your result in the data sheet.
5. When you enter the data on-line, the data portal will automatically calculate the amount of CO_2-C lbs/acre/day at 24 hours. Verify that your calculations coincide with the data portal numbers.

Temperature conversion to field conditions

Use Table 7 to determine the CO_2-C emissions at field temperature based on your results at room temperature at 24 hours following the steps below. The data portal will automatically make these calculations after you enter on-line the color numbers and the soil temperature readings at 5 cm.

1. Calculate the average field soil temperature at a 5 cm depth based on the data recorded when you collected the composite soil sample. When you enter these data on-line, the average soil temperature at 5 cm is automatically calculated.
2. In Table 7 find the average field soil temperature and the respective conversion factor.
3. Divide the CO_2-C value at room temperature after 24 hours, found in Table 6, by the conversion factor found in Table 7. Do this calculation for both numbers of the range.
4. Find this new CO_2-C value in Table 6. This value indicates the CO_2-C emissions at field temperature at 24 hours. Record this value in your data sheet.
5. If you obtain a value that is greater than 160, this indicates that your soil sample has extremely high biological activity. This could be the result of a soil very rich in organic matter and or high soil temperatures.
6. Verify that your calculations coincide with the data portal numbers.

Table 6. Solvita Field Test – Performed in test jar at 20-22°C (68-72°F) after 24 hours

Color reading of gels in paddles					
Blue-Gray Color 0 - 1.0	Gray-Green Color >1.0 - 2.5	Green Color >2.5 - 3.5	Green-Yellow Color >3.5 – 4.0	Yellow Color >4.0 – 5.0	Bright Yellow Color >5.0 – 6.0
Biological soil condition of cultivated soils					
Extreme Low Activity	Low Activity	Medium – Low Activity	Ideal Activity	Medium – High Activity	Very High Activity
Associated with extremely depleted soils	Marginal biological activity with low organic matter	Medium activity - may be accumulating organic matter	Active microbe population and good organic matter supply	Very active biologically with very high organic matter turnover	High biological activity with excellent supply of organic matter
Emissions (Flux) of CO_2-C as lbs / acre / day *					
0.5 - 1	>1 - 5	>5 - 15	>15 - 25	>25 - 60	>60 - 160
International emissions (flux) of CO_2 as grams / m^2 / day **					
0.2 – 0.4	>0.4 – 2	>2 – 6	>6 – 10	>10 - 25	>25 - 65

***** Units are CO_2-C (amount of carbon in the CO_2 gas). Results are likely to depend on a variety of factors such as depth of sampling, soil temperature, and field moisture.

****** International Metric Units based on CO_2. To convert CO_2 values to CO_2-C, multiply CO_2 values by 0.273. To convert CO_2-C values to CO_2, multiply CO_2-C values by 3.7.

Table 7. Conversion of CO_2-C emissions at room temperature (20°C /70°F) to emissions at field temperature

Field soil temperature *	**5°C**	**10°C**	**15°C**	**20°C**	**30°C**	**40°C**
Conversion factor	4	2	1.5	1	0.5	1

*****If your average temperature in the field is an intermediate number between the values in this table, use intermediate values of the conversion factor. For example, if the average temperature is 25°C, divide your CO_2-C value by the conversion factor 0.75.

SOIL WATER-FILLED PORE SPACE, WATER CONTENT, AND BULK DENSITY PROTOCOL

Background

At the soil surface, carbon, nitrogen, and water can accumulate in large quantities leading to greater numbers of soil microbes and microbial activity. Aerobic microbial activity increases with soil water content until water displaces the air, restricting the availability of oxygen. At relatively high water content when aeration is not a limiting factor, microbial respiration, nitrification, and mineralization occur at maximum rates. Consequently, when soil water content reaches or exceeds field capacity, the percentage of space of soil pores filled with water is a good indicator of microbial activity. In general, maximum aerobic microbial activity is reached at 60% WFPS. Below this point, water limits microbial activity, and above 60% of WFPS, aerobic microbial activity decreases. Percent water-filled pore space (%WFPS) is determined by soil water content and soil bulk density.

Soil water content is expressed as the mass (weight) of water in a soil sample (Gravimetric water content) and as the volume of water in a known volume of soil (Volumetric water content). How much water is stored in the soil determines the soil's ability to moderate the hydrological cycle, influences weather and climate, and maintains soil-water balance. Soil moisture also influences other soil properties (color, pH, horizons) and processes. Soil processes such as soil respiration and decomposition of organic matter are influenced by soil moisture's effect on microbial activity. Soils saturated with water can be unhealthy, supporting only anaerobic microbial activity and promoting plant roots decay over time. On the other hand, in dry soils, the relatively few water molecules are strongly attached to soil particles preventing the use by soil organisms.

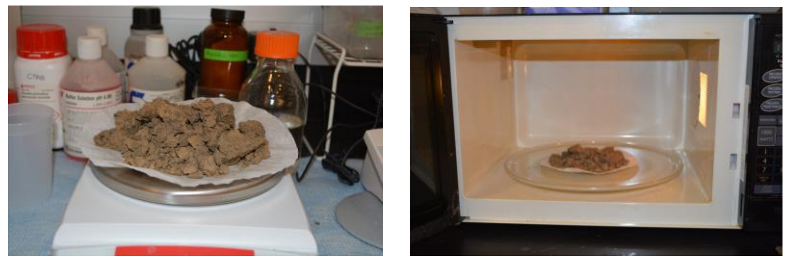
Soil bulk density is an indicator of soil compaction. Bulk density is the dry weight of soil for a given volume, where the volume includes the volume of particles (sand, silt, and clay) and pore space between the particles. At high bulk density, less pore space is available in the soil for oxygen, water movement, root growth, and microbe and animal activity. Bulk density can be dramatically altered by land use practices such as cultivation, trampling by stock animals, agricultural machinery, construction, and weather. Activities that compact the soil increase bulk density.

Materials (some are optional)

- Balance or scale (0.1 grams precision and 400 grams minimum capacity)
- Brush
- Clipboard and data sheet
- Compostable bowls (5)
- Hot pad/oven mitt
- Knives: table knife and flat-bladed knife (pocket knife)

Bulk density sampling.

- Metal ring (7.62 cm diameter x 6.98 cm height)
- Oven capable of maintaining a temperature not exceeding 105°C, **or** a 250 Watt infrared heating lamp (1 or 2 bulbs) that reaches temperatures of 65-90°C, **or** a fan
- Newspaper (if you air dry the soil samples)
- Permanent marker
- Rubber mallet
- Sealable bags (5)
- Soil sample
- Spatula
- Tray
- Trowel
- Wooden block



Weighing and drying a soil sample.

Sampling guidelines

- Soil bulk density is measured once per year at one replicate location (R1) during the first survey. This measurement is used to calculate % Volumetric water content, % Total porosity and % Water-filled pore space.
- % Gravimetric water content is measured every month from a composite soil sample, except during the first survey when the soil sample is obtained from the soil bulk density collection.
- The soil sample to calculate water content is taken from the top 7 cm of the soil.
- Readings of soil temperature and air temperature can be taken at the same time.

Measurement procedures

*Soil bulk density **once per year** - In the field - See video at modirt.missouriepscor.org/node/305*

1. **If your survey site is rocky,** you cannot measure soil bulk density. Continue with the procedure of "Water content once a month" in page 46.
2. If the survey site is **not** rocky, in the location of replicate 1 (R1) clear an area of leaf litter, rocks, and debris until the soil is exposed and flat. Avoid areas with soil cracks.
3. Place the metal ring on the ground with the beveled edge down.
4. Push the ring into the soil with your hands as far as you can so that the bottom of the ring is even with the ground surface. In case you can only partially push the ring, measure the height of the ring that is not in the soil. Deduct this height from the total ring height (6.99 cm) to have the height of the ring that is in the soil for future calculations in page 47. Push the ring, keeping it straight. If the ring does not go all the way down, place a wooden block on top of the ring and **gently** hammer the ring into the soil with a rubber mallet until the top of the ring is at surface level (see photo in page 43). The wooden block spreads the force of the hammer evenly to make the ring descend evenly into the soil.
5. **If a rock or a big root is interfering in the soil ring collection**, start over in a new spot some centimeters away within your replicate site.

6. Avoid excessive compression of the soil. Compare the soil elevation inside the ring with the original soil surface outside the ring as you insert the ring. They should be the same.
7. To remove the ring when it is buried at the same level of the soil, do the following:
   - Dig deep and wide around the ring using the table knife and trowel.
   - To lift the ring out while preventing any loss of soil inside the ring, place the wooden block on top of the ring, and the wide plastic spatula underneath the ring. Allow some soil between the ring and the spatula.
   - Lift the ring and turn the sample upside down with the wooden block as the base and the spatula on top.
8. Remove any excess soil from the top of the ring using the spatula or the flat-bladed knife (pocket knife) until the soil is flat and even with the edges of the ring.
9. Invert the sample again with the spatula at the base, lift the wooden block and, using the flat-bladed knife, even the soil with the edges of the ring if necessary.
10. Using as little hand contact as possible, place the soil sample in a sealable bag to prevent additional soil moisture loss. Use the table knife to push the soil out of the ring and make sure the entire sample is placed in the bag. Seal the bag tightly and write on it the site name, date, and bulk density.
11. Prevent the sample from being exposed to sunlight and heat and bring it to the lab as soon as possible for processing.
12. Clean the ring with the brush.

*Soil bulk density **once per year** - In the lab*

1. As soon as possible, return to the lab to process the sample. If you cannot work on the sample right away, make sure the bag is sealed tightly and store it in a cool place away from sunlight and changes in temperature.
2. Weigh the soil sample in its bag and record the value in the data sheet (Page 6 of form, column A).
3. Weigh a clean bag (same size) and record this value in the data sheet (Page 6 of form, column B). The bag weight accounts for the weight of the bag where the sample is.
4. Subtract the clean bag weight from the soil-filled bag weight to determine weight of wet soil (Page 6 of form, column C), and record this value in the data sheet. If you enter the values of A and B on-line, C is automatically calculated.
5. Keep the bag sealed and mix the sample in the bag by kneading it with the fingers.
6. Depending on the drying method, follow the next steps:
   - If you use the compostable bowls as containers for the drying process, weigh a bowl and record it in the data sheet (Page 6 of form, column E). This value accounts for the weight of the bowl where you place a soil sample.

Oven:
   - Make sure that the oven is not used for food.
   - Place the soil sample in a compostable bowl in the oven. The temperature of the oven should not exceed 105°C. Dry the sample for a couple of hours. Check after one hour to see if the sample is fully dry. If not, move the soil around with a table knife and keep drying it until it is.
   - Re-weigh the bowl with soil each cycle until the weight no longer changes.

Lamp:
- Place the soil sample in the bowl under a lamp to dry for at least 2 days. Avoid contact with the lamp.
- Move the soil around in the bowl with a table knife twice a day to speed up the drying process.
- Re-weigh the bowl with soil periodically until the weight no longer changes.

Air dry and fan:
- Place the soil sample in the bowl and let it air dry for 2-5 days.
- Use a fan, if available, to speed up the drying process.
- Move the soil around in the bowl with a table knife twice a day to speed up the drying process.
- Re-weigh the bowl with soil periodically until the weight no longer changes.

7. Record the value of dry weight of soil with container in the data sheet (Page 6 of form, column D).
8. Subtract the bowl weight from the soil + bowl weight to determine the weight of dry soil (Page 6 of form, column F), and record it in the data sheet. If you enter the values of D and E on-line, F is automatically calculated.
9. Record the volume of your sample (Page 6 of form, column G). This volume is 292.53 cm^3 if you collected soil that filled the whole ring. If the soil sample did not fill the whole ring, adjust the formula of volume (See page 47 for volume adjustments).
10. Make the calculations for columns H through L (H - bulk density, I -% Gravimetric water content, J - % Volumetric water content, K - % Total soil porosity, L - % Water-filled pore space). These calculations are explained in page 47. If you enter the values of A through G on-line, the calculations for H through L will be automatically calculated.
11. After the volume of soil (G) and soil bulk density (H) are on-line, their values are locked and are used automatically in future monthly calculations of variables I through L.
12. If the calculations are done automatically on-line, it is recommended that you copy the values of these calculations in your form every month to have a print copy of your data.
13. Cleaning: At the end of the experiment clean the equipment with mild soap and water (except wooden blocks and bowls). Remove all soil from bowls with a cloth or brush and avoid contact with water. If damaged, dispose of them in a compost site.

*Water content **once a month** (except the month bulk density is measured)*

1. Use two cups of soil from the composite sample (see protocol in page 37) to calculate wet (C) and dry weight (F) of soil every month. Follow steps 1-8 in the section “Soil bulk density once per year - In the lab”.
2. **If** bulk density (H) has been collected for the site, you can make the calculations of I to L, or enter the data of A to F on-line to obtain automatic calculations of I to L.
3. **If** bulk density **cannot** be collected in your site, you only can calculate % Gravimetric soil water content (I) (see page 47 for this calculation). If you enter the values for wet and dry soil on-line (A, B, D and E), gravimetric water content will be automatically calculated.
4. During the surveys of May and August, use your dry soil sample for the organic matter protocol (page 58).

Calculations of soil bulk density, volumetric water content, and percent water-filled pore space (WFPS)

With the values for weight of wet and dry soil, you can calculate soil parameters related to water content such as bulk density, gravimetric and volumetric water content, total porosity, and water-filled pore space using the following formulas. You have the option to enter the values on-line for wet and dry soil, and automatically the water content parameters will be calculated.

Bulk density is needed to calculate % Total soil porosity. % Gravimetric water content is needed to calculate % Volumetric water content. % Volumetric water content and % Total porosity are needed to calculate % Water-filled pore space.

Letters in parentheses after each variable indicate the columns of these variables in the data sheet.

1. Soil bulk density (g/cm^3) (H) = Weight of dry soil (F) / volume of soil sample (G). Where …

- **Volume of soil sample (G)** = ring volume = $\pi \times r^2 \times L$ = 3.1416 x 13.32 x 6.99 = 292.53 cm^3

  L = height of ring = 6.99 cm *
  r = radius = 3.65 cm (r= diameter/2 = 7.3/2 = 3.65 cm)

Notes:
*In case you cannot obtain a soil sample that fills the whole ring (e.g., hard dry soils may prevent to insert the ring all the way to the soil level), the height of the ring (L) needs to be replaced in the formula by the height that the soil sample occupies in the ring.

2. % Gravimetric soil water content (I) = [(weight of wet soil (C) – weight of dry soil (F)) / weight of dry soil (F)] x 100. Where …

- Weight of wet soil (C) = (weight of wet soil + bag (A)) – weight of bag (B)
- Weight of dry soil (F) = (weight of dry soil + container (D)) – weight of container (E)

3. % Water-filled pore space (%WFPS) (L) = (% Volumetric water content (J) / % Total soil porosity (K)) x 100.
Where …

- **% Volumetric water content (J)** = (% Gravimetric soil water content (I)) x (Soil bulk density g/cm^3 (H))
- **% Total soil porosity (K)** = [1 – (Soil bulk density (H) / Soil particle density)] x 100

Soil particle density is assumed to be 2.65 g/cm^3. You may result with a %WFPS over 100. This could be due to the variation in the number of decimal points.

Data interpretation

The figure below shows a model of the behavior of microbial activity in the soil at different percentages of water-filled pore space (Figure 6). Compare your results with respect to 60 %WFPS, the value at which microbial activity is at its maximum.

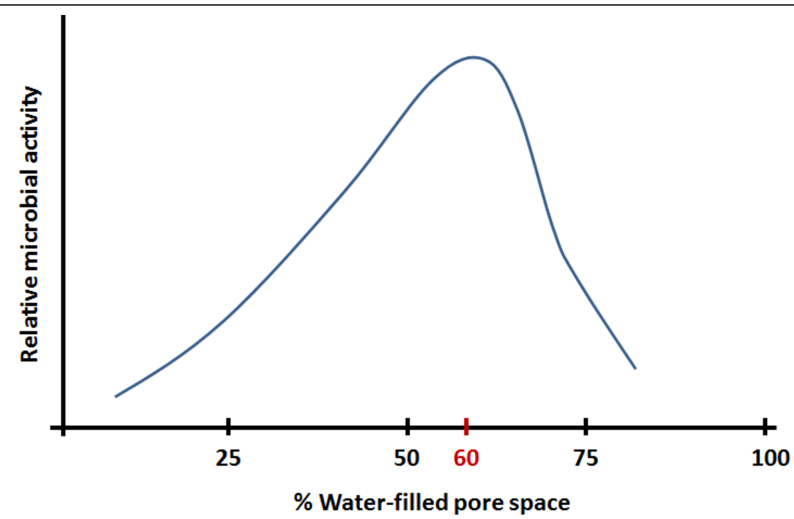


Figure 6. Model of microbial activity in relation to water-filled pore space. Model modified from Bowman 1998 and Linn and Doran 1984.

The table below provides information of ideal bulk density values for plant growth based on soil texture as well as values where root growth is restricted (Table 8). This table does not apply to red clayey soils and volcanic ash soils.

Table 8. Bulk density values for soils with different textures

Soil texture	Ideal bulk density for plant growth (g/cm^3)	Bulk density that restricts root growth (g/cm^3)
Sand, loamy sand	<1.60	>1.80
Sandy loam, loam	<1.40	>1.80
Sandy clay loam, clay loam	<1.40	>1.75
Silt, silt loam	<1.40	>1.75
Silt loam, silty clay loam	<1.40	>1.65
Sandy clay, silty clay, clay loam	<1.10	>1.58
Clay (>45 percent clay)	<1.10	>1.47

Safety instructions

- When using the oven, avoid touching hot surfaces and materials.

PROTOCOLS FOR VARIABLES TO MEASURE TWICE A YEAR

SOIL NUTRIENTS PROTOCOL

Background

Plants require *nutrients*, water, air, heat and sunlight to grow. The nutrients that plants need in large amounts are *macronutrients,* and the ones that are needed in small amounts are *micronutrients*. The fertility of the soil indicates the availability of these nutrients for the plants. Three macronutrients that are particularly important for plants to grow are nitrogen, phosphorous and potassium. These nutrients are used as parameters of soil fertility. Potassium ions are positively charged and held in the soil by negatively charged soil particles. Nitrogen and phosphorous are negatively charged and are *not* held very well by soil particles. Consequently, these two elements are easily lost from the soil due to leaching (removal from the soil as water passes through it).

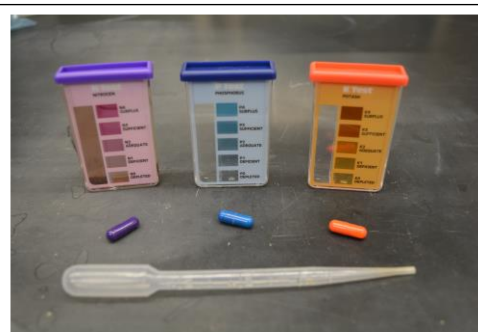
Nitrogen (N) is an element found in the atmosphere in high concentrations, but in the soil, it is found in low concentrations. Nitrogen is an important component of plant proteins and nucleic acids (DNA, RNA) and promotes vegetative growth on plants. However, nitrogen cannot be used by plants in its natural form. In soil and water, inorganic nitrogen is transformed to nitrate (NO_3, the most common), nitrite (NO_2), or ammonium (NH_4), all of which are usable forms for plants. These forms of nitrogen are easily lost in the soil through leaching or evaporation. Nitrogen-fixing plants such as legumes, certain microbes, and decomposing organic matter restore nitrogen levels.

Phosphorous (P) is important in the energy pathway of plants since it is an important element in the composition of DNA and RNA. Phosphorous is available to plants in the form of phosphate ions (PO_4^{-3}). Phosphate can only be taken effectively up by plants when soils have a pH range of 5.0-8.0. A lack of phosphorous results in slow growth of plants, and decreased expansion of roots. Phosphate is also easily leached from the soil.

Potassium (K) is a component of cell walls and is essential to activate cell enzymes in plants participating in the control of cellular turgor (pressure against cell walls due to the influx of water in the cell), increasing fruit size and its flavor, having a positive effect on color and fragrance of flowers, and making the plants more resistant to diseases. This element is readily available to plants, and because of its positive charge, it is easily stored in the soil.

Materials

- Brush
- Clipboard and data sheet
- Composite soil sample
- Distilled water
- Nitrile gloves
- Permanent marker
- Plastic squeeze bulb pipette



Soil comparators with matching color pills and plastic squeeze bulb pipette

- Plastic container (1 L)
- Rapitest Soil Test Kit (3 color comparators for N, P, and K, and pills of matching colors)
- Set of measuring cups
- Watch or timer

Sampling guidelines

- The soil used in this protocol is from a composite soil sample. See protocol in page 37.
- The soil is taken from the top 7 cm of the soil twice per year (May and August).
- There is one value for this variable (instead of five) per sampling.
- Use the waiting time in this protocol to collect data for other variables.

Measurement procedures

In the lab:

1. Place ½ cup of soil from the leftovers of the composite soil sample and 2 ½ cups of distilled water in a plastic container (1 L).
2. Mix the soil solution for 1 minute. Let the solution stand undisturbed for 1 hour. A fine clay soil (very turbid water) will take much longer to settle out than a coarse sandy soil. The clarity of the solution will also vary, the clearer the better, however cloudiness will not affect the accuracy of the test.
3. For each of the three analyses of N, P, and K: Match the pill capsules with the color comparators (small plastic containers) of the same color and verify that the film color charts are in place.
4. Use a plastic squeeze bulb pipette to fill both the test and reference chambers (narrow and wide chambers respectively) with the liquid part of the soil solution. Fill both chambers up to the dotted line shown in the test chamber. Avoid pipetting debris at the surface and or soil at the bottom.
5. Add the content of a capsule of the matching color to the test chamber (narrow chamber). To do this, hold the capsule horizontally over the test chamber and carefully separate the two halves to pour the powder into the chamber. Make sure the capsule is totally emptied.
6. Cover the comparator tightly with the cap and mix well. Allow the comparator to sit undisturbed for 10 minutes for the color to be revealed. After exactly 10 minutes, compare the color of the soil solution in the test chamber with the color on the color chart. Record the value on the data sheet, as well as the respective equivalency in parts per million (ppm) (Table 9, page 52).
7. If after the 10 minutes a colored layer has formed at the bottom of the test chamber, gently tilt the comparator back and forth a few times. The colored layer will mix with the soil solution changing its color. Then, do the reading of the colors.
8. For better results, use the daylight rather than direct sunlight to help you identify the colors. Look through the test chamber in the light.
9. At the end of the experiments, clean the materials with mild soap and water.

10. Make sure the color charts, comparators, and lids match colors for their use in the next survey.

Safety instructions

Dispose of the test solutions by rinsing them down the sink. Empty gelatin capsules should be disposed of immediately with household waste. Remove color charts and wash the containers and caps in warm soapy water immediately after each use. Make sure any sediment or color staining is removed. Rinse well and dry. Store the kit in clean, dry conditions that are also indoors and away from children. Avoid touching the powders and always wash your hands thoroughly after conducting your tests. Do not drink, eat, or smoke while using the soil test kit. Keep powders away from food, drink and animal feed. If taken internally, drink copious amounts of water and seek medical advice.

Data interpretation

The table below indicates the equivalency of the colors in the comparators in parts per million for nitrogen, phosphorous and potassium (Table 9).

Table 9. Equivalency of the test categories for each of the nutrients (N, P, K) in parts per million (Mg/Liter)

	Depleted	Deficient	Adequate	Sufficient	Surplus
N	**N0**	**N1**	**N2**	**N3**	**N4**
Nitrate (NO_3)	0	10	20	40	80
P	**P0**	**P1**	**P2**	**P3**	**P4**
Phosphoric Acid (P_2O_5)	5	10	20	50	100
K	**K0**	**K1**	**K2**	**K3**	**K4**
Potassium Oxide (K_2O)	50	200	400	600	900

pH PROTOCOL

Background

pH is a parameter used to describe how acidic or basic (the opposite of acidic) a solution is. This parameter is determined by the amount of hydrogen ions (H^+) in a sample. The pH scale ranges between 1 and 14, and the lower the number the more acidic the pH of a sample is (more H+ ions). A pH around 7 is neither acidic nor alkaline, but considered to be neutral. Values of pH 8 and above are considered to be alkaline. Soils with extreme pH values may break down easier so that the soil structure and composition is not so stable. Soil acidity or alkalinity (soil pH) influences how plants grow and what kind of microorganisms may live in a soil. Soil pH is important because it determines how available nutrients may be to a plant and how easily plants can take up nutrients from the soil. Most nutrients that plants need can dissolve easily when the pH of the soil solution ranges from 6.0 to 7.5. Below pH 6.0, some nutrients, such as nitrogen, phosphorus, and potassium, are less available. When pH exceeds 7.5, iron, manganese, and phosphorus are less available. Soil pH is also an important measurement to assess the potential availability of toxic elements to plants.

With a few exceptions, most plants will tolerate a fairly wide range of soil pH. Many environmental factors, including the amount of rainfall, the vegetation type, and temperature, can affect soil pH. In general, areas with heavy rainfall and forest cover have moderately acid soils. Soils in regions with light rainfall and prairie cover, such as in parts of the Midwest, tend to be near neutral. Areas that experience a lot of drought tend to have alkaline soils. The pH of cultivated and developed soils often differs from that of the native soil because during construction of buildings, or poor farming practices, topsoil is frequently removed or lost and may be replaced by a different type of soil.

Materials

- Brush
- Clipboard and data sheet
- Composite soil sample
- Distilled water
- Nitrile gloves
- Permanent marker
- Plastic squeeze bulb pipette
- Rapitest Soil Test Kit (1 color comparator
- for pH and a pill of matching color)
- Watch or timer

Soil comparator with matching pill and plastic squeeze bulb pipette

Sampling guidelines

- The soil used in this protocol is from a composite soil sample. See protocol in page 37.
- The soil is taken from the top 7 cm of the soil twice per year (May and August).
- There is one value for this variable (instead of five) per sampling.
- Use the waiting time in this protocol to collect data for other variables.

Measurement procedures

1. Open the pH container from the Rapitest Soil Test Kit. Have a color-matching pill ready.
2. Fill the test chamber (left, narrow chamber) of the color comparator (small plastic container) with soil from the leftovers of the composite soil sample up to the "soil fill line."
3. Carefully empty the capsule in the test chamber. To do this hold the capsule horizontally over the test chamber and carefully separate the two halves to pour the powder into the chamber. Make sure the capsules are totally emptied.
4. Add distilled water with a plastic squeeze bulb pipette up to the "fill with water" line shown on the test chamber.
5. Cover the container tightly and mix very well.
6. Allow the soil sample to settle to the bottom and wait for the color to be revealed (1 min).
7. Compare the color of your soil solution against the colors in the chart to determine the pH of your solution and record your result in the data sheet. For better results, use the daylight rather than direct sunlight to compare the colors.
8. At the end of the experiments clean the materials with mild soap and water.

ACTIVE CARBON PROTOCOL

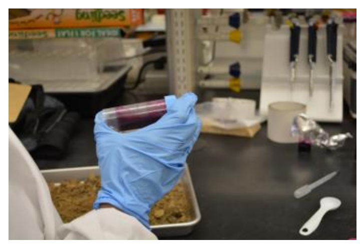
Background

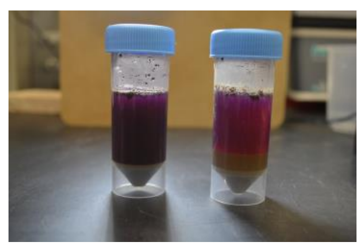
Soil organic matter (SOM) is a widely acknowledged indicator of soil health. However, it does not have a definite chemical composition. The dominant element in SOM is soil organic carbon (SOC). Soil organic carbon contains high levels of recalcitrant forms (slowly altered by microbial activity) and small portions of labile fractions (decomposing readily). The labile fraction or active carbon is the type of carbon in the SOM that is readily available to the soil microbial community as a source of energy and carbon, driving much of the biological activity in the soil and the cycling of nutrients. Active carbon has fractions of microbial biomass carbon, particulate organic matter (particles less than 2 mm and greater than 0.053 mm in size), and soil carbohydrates.

Active carbon as a soil health indicator is positively correlated with percent organic matter, aggregate stability and with soil respiration rate, a measure of biological activity in the soil. Active carbon is very sensitive to land management practices and soil productivity, responding much sooner to changes in land management practices than total organic matter.

Materials

- Balance or scale (0.1 grams precision and 400 grams minimum capacity)
- Brush
- Clipboard and data sheet
- Color chart
- Composite soil sample (air dry)
- Distilled water
- Free-standing tube (30 ml)
- Nitrile gloves
- Plastic squeeze bulb pipette
- Potassium permanganate solution (0.2 *M* $KMnO_4$ in 1 *M* $CaCl_2$, 7.2 pH) (5 ml), (store in a cool place).
- Set of measuring spoons
- Tray
- Watch or timer





Preparation of soil solution, mixing, and soil color comparisons.

Sampling guidelines

- The soil used in this protocol is from a composite soil sample. See protocol in page 37.
- The soil is taken from the top 7 cm of the soil twice per year (May and August).

- There is one value for this variable (instead of five) per sampling.
- Use the waiting time in this protocol to collect data from other variables.

Measurement procedures

1. From the leftovers of the composite soil sample, take a soil subsample (1/4 cup).
2. Using gloves, crumble the soil gently to give an even, aggregate consistency and spread thinly on the metal tray.
3. Remove organic matter from the soil sample (e.g. roots, leaves, bark, animals, etc.) as well as rocks and any other big debris.
4. If the soil is moist, air-dry it for a couple of days. Mix the soil 2-3 times while drying. Do not use extreme heat.
5. Place 2 ml of the 0.2 *M* $KMnO_4$ solution in the free-standing tube and add distilled water to the 20 ml mark. Cap the tube and mix the solution.
6. Add 5 g of soil to the solution.
7. Cap the tube tightly and shake vigorously for **exactly** 2 min (~100 strokes/min) to oxidize the active carbon in the sample. Stand the tube on the tray for **exactly** 10 minutes, avoiding any kind of disturbance. Protect the sample from direct sunlight while the soil particles settle.
8. After the 10 minutes, use the color chart to determine the level of active carbon in the sample and record the results in the data sheet. The purple color becomes lighter as a result of the oxidation of the carbon.
9. At the end of the experiment, dispose of the solution in a sink, flush with water, and clean the materials with mild soap and water.

Safety instructions (see Appendices for Safety Data Sheet)

- Potassium permanganate is a very powerful oxidizer and should not be stored near acids or fuel sources to prevent fires, explosions, and or toxic gas buildup.

- The storage of this chemical (powder) should be in a clean and dry sealed container. It can be stored for over a year.

- When the powder is mixed with water, it becomes a powerful dye and stains fabrics permanently, stains skin temporarily, and causes corrosion on any metal or masonry.

Data interpretation

Potassium permanganate ($KMnO_4$) is an oxidizing agent that reacts with active carbon to partially bleach the deep purple permanganate color to light pink or clear. The safety data sheet for potassium permanganate is in Appendix 3). The lighter the color of the $KMnO_4$ solution after reacting with the soil, the greater the amount of active carbon and the better the quality of the soil.

The table below indicates soil quality based on the potassium permanganate method to estimate relative amounts of active carbon (Table 10).

Table 10. Field color chart to estimate the amount of active carbon in a soil sample using the potassium permanganate test

Soil quality	**Poor**	**Fair**	**Good**	**Excellent**
Active carbon in pounds per acre (lbs/A)	> 0 – 232	> 232 – 464	> 464 – 928	> 928

SOIL ORGANIC MATTER PROTOCOL

Background

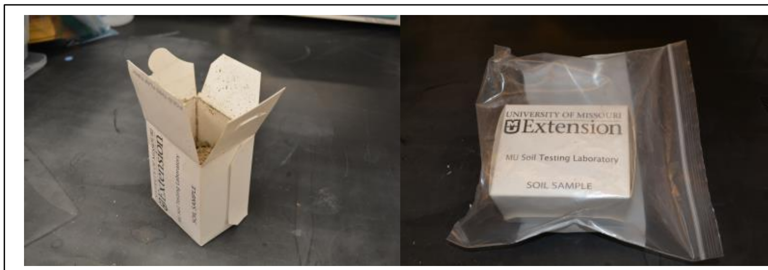
Soil organic matter (SOM) is the organic component of soil and consists of fresh plant residues (<10 %), small living soil organisms (<5%), decomposing organic matter (active fraction; 33-50%), and stabilized organic matter (humus; 33-50%). Soil organic matter is the most important indicator of soil health and it plays many roles. It provides food for microorganisms that themselves facilitate the availability of nutrients for plants, minimizes leaching of nutrients, buffers the effects of high acidity, increases the moisture retention of the soil, the available water capacity and water filtration, helps to minimize compaction and surface crusting, holds soil aggregates together, decomposes toxic substances, and acts as a carbon sink.

The amount of organic matter in the soil ranges from less than 1% in sandy desert soils to 10-20% in forested or very poorly drained soils. In most productive agricultural soils, SOM ranges between 3-6%. In general, optimal SOM ranges between 6-8%. These numbers are going to vary by the influence of several factors on the rate of decomposition of the soil organic matter such as climate, land management, type of vegetation, texture and drainage.

Some generalities about SOM include:
- Grassland soils have higher SOM than forest soils.
- SOM increases with increasing precipitation and decreases with increasing temperature.
- Fine-textured soils have higher SOM than coarse-textured soils.
- Somewhat poorly and poorly drained soils have higher SOM than well drained soils.
- Soils in lowlands have higher SOM than soils on upland positions.

Materials

- Balance or scale (0.1 grams precision and 400 grams minimum capacity)
- Permanent marker
- Pre-paid post office envelope
- Sealable bag
- Soil box
- Soil sample from the bulk density protocol



Soil sample in soil box and in sealable bag.

Sampling guidelines

- The soil used in this protocol is from a composite soil sample or bulk density sample.
- The soil sample is from the top 7 cm of the soil.
- Organic matter is tested twice per year (May and August) if your site experiences major disturbances (e.g. flooding, burning, logging, crop and pasture management, etc.). If your site

does not experience major disturbance (e.g. forest, woodland, abandoned grassland), you can collect a single soil sample in either May or August.

- There is one value for this variable (instead of five) per sampling.

Measurement procedures

In the lab:

1. Use approximately 1 ½ cups of soil from the composite soil sample. You may use soil from the bulk density sample if you started your project in the months of May or August.
2. Remove organic matter from the soil sample (e.g. roots, leaves, bark, animals, etc.) as well as rocks and any other big debris.
3. Place the sample in the soil box from the University of Missouri Extension and label it with a name, address, date of collection, and habitat type. Disregard other requested information and procedures in box.
4. Avoid placing in the box soil that is too humid. Let it air dry for a couple of days before mailing it.
5. Weigh the sample and make sure it weighs **maximum 283 gr (10 oz)**.
6. Place the box in a sealed bag and then in the pre-paid envelope. The pre-paid envelope with the sample inside has to weigh **less than 368 gr (13 oz).**
7. Deliver the envelope promptly to the Donald Danforth Plant Science Center (Sandra Arango-Caro, Education & Outreach, 975 N Warson Rd., St. Louis, MO 63132).
8. Keep the sample away from sunlight and heat until delivered or mailed.

Data management

The sample will be analyzed at a soil testing laboratory using the Loss-On-Ignition (LOI) method. This method involves estimating organic matter by measuring the weight loss after the ignition and burning of the organic matter.

The Danforth Center will inform the participants of the result of their samples. Make certain the Education and Outreach staff have your e-mail and phone number.

RECOMMENDATIONS TO CONDUCT A SOIL SURVEY

The following steps will help you prepare to conduct the soil health survey in an efficient and proper way. The soil survey manual provides detailed information about each step.

BEFORE YOU GO TO THE FIELD

- ☐ Read the instructions for collecting the data for each of the variables before you start with the survey.
- ☐ Review topographic and soil survey maps to select your survey site and the potential location of replicates within the site.
- ☐ Make sure that you have all the materials and equipment needed to conduct the survey and that everything works properly.
- ☐ Review the Soil Survey form to make sure you understand how to fill it out.
- ☐ Carry in your backpack only the materials that you are going to need for the particular survey. Look in Table 5 (page 23) to determine which variables are measured when and in Table 13 (page 62) to determine the materials and equipment to bring to the field and the ones that stay at the lab.
- ☐ Discuss with the members of the group who will be doing what and assign tasks. The collection of some data can be done simultaneously.

DURING THE SOIL SURVEY (FIELD AND LAB)

- ☐ Visit the potential location of the replicate sites and decide where to set them up for the collection of data.
- ☐ Mark the replicate sites.
- ☐ Collect the data in the following order to use the time efficiently.

In the field:

1. During sampling reduce the disturbance caused by the sampling as much as possible.
2. Collect **air and soil temperature.**
3. While waiting for the stabilization of these measurements work on the collection of the **composite soil sample.**
4. Collect the sample for **soil color, texture, and bulk density** when apply.

In the lab:

1. Start the **soil respiration** test.
2. Start the soil drying process to calculate **water content and bulk density** when apply**.**
3. Conduct the **soil nutrients** and **pH** tests (May and August).
4. Conduct the **active carbon** test (May and August).
5. Prepare the soil **organic matter** sample to ship back to the Donald Danforth Plant Science Center (DDPSC) (May and August).

- ☐ Avoid collecting data from the same spots within each replicate location for monthly surveys.
- ☐ Make sure that you fill all the parts of the form. An empty cell indicates that you forgot to collect the respective information, unless you explain why you do not have the information available for a particular cell (e.g., no signs of erosion, no information available on the history of the site, thermometer run out of battery, etc.).
- ☐ Collect the data, and make sure you write the information correctly (units, location in the data sheet, complete details, etc.).
- ☐ Return as soon as you can to your laboratory setting (classroom, lab, office, kitchen, etc.) to process your samples. Some tests can be run the next day.
- ☐ Clean your equipment and wash any other supplies with soap and water to have them ready for the next survey.

AFTER YOU CONDUCT THE SURVEY

- ☐ Send the soil organic matter sample by mail to the DDPSC when apply.
- ☐ Enter the information from your data sheet in the MO DIRT website (under construction now).

Timeline of the variables measured in a soil health survey over time with the number of replicates and readings per variable per survey

No. of replicates	No. of readings per variable	Variables	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Once a year measurements												
1	1	Soil color [a]	Measured at any survey									
1	1	Soil texture [a]	Measured at any survey									
Monthly measurements												
1	1	% cloud cover [b]	x	x	x	x	x	x	x	x	x	x
5	5	Air temperature [b]	x	x	x	x	x	x	x	x	x	x
5	5	Soil temperature	x	x	x	x	x	x	x	x	x	x
5	1 [c]	Soil respiration	x	x	x	x	x	x	x	x	x	x
5	1 [c]	Soil water content	x	x	x	x	x	x	x	x	x	x
1	1	Bulk density [d]	Measured during the first survey									
1	1	Water-filled pore space [e]	x	x	x	x	x	x	x	x	x	x
Twice a year measurements [f]												
5	1 [c]	Soil fertility (N, P , K)				x			x			
5	1 [c]	pH				x			x			
5	1 [c]	Active carbon				x			x			
5	1 [c]	Soil organic matter				x			x			

[a] It is recommended that these measurements be taken at the beginning of the project.

[b] % cloud cover and air temperature are part of the site description, not soil health indicators.

[c] Measurement from a composite soil sample obtained from soil collected in the five replicate locations.

[d] Although it is a variable that is measured once a year, its value is used to calculate water-filled pore space on a monthly basis.

[e] Soil water content and bulk density are used to calculate water-filled pore space.

[f] The twice a year measurements are collected in May and August if your site experiences major disturbances (e.g. flooding, burning, logging, crop and pasture management, etc.). These measurements can be collected once in either May or August, if your site does not experience major disturbance (e.g. forest, woodland, abandoned grassland).

Table 13. List of materials and equipment by variable, to use in the field (F) and or the lab (L), provided by MO DIRT and by the participants

MATERIALS AND EQUIPMENT	Set up of replicates	Slope	Soil color	Soil texture	Air temp.	Soil temp.	Composite soil sample	Soil resp.	Bulk density & water content	Soil nutrients	pH	Active carbon	Organic matter
PROVIDED BY MO DIRT													
Active carbon kit												L	
Auger - 12 inches			F	F									
Backpack	F	F	F	F	F	F	F		F				
Balance								L	L			L	
Brush				F, L		F		L	L	L	L	L	
Clipboard		F	F	F	F	F		L	L	L	L	L	
Compost bowls (4)									L				
Distilled water (1 gallon)			F	F				L		L	L	L	
Line level		F											
Manual	F	F	F	F	F	F	F	L	L	L	L	L	L
Measuring tape	F	F			F								
Metal ring									F				
Nail						F							
Nitrile gloves (1 box)							F	L		L	L	L	
Plastic container (1 L)										L			
Permanent markers (2)	F	F	F	F	F	F	F	L	L	L	L	L	L
Plastic pipette, 3 ml (3)			F	F				L		L	L	L	
Pre-paid envelope													L
Rapitest kit										L	L		
Rubber mallet	F		F	F					F				
Sealable bags (20)							F		F				
Set of measuring spoon/cup										L		L	
Sign "Research site"	F												
Soil and air thermometer					F	F							
Soil box													L
Soil color book			F										
Soil texture diagram				F									
Solvita kit								L					
Spatula									F				
Stakes (6)	F												
Stick		F		F									

MATERIALS AND EQUIPMENT	Set up of replicates	Slope	Soil color	Soil texture	Air temp.	Soil temp.	Composite soil sample	Soil resp.	Bulk density & water content	Soil nutrients	pH	Active carbon	Organic matter
String		F											
Table knife				F					F				
Tray								L	L			L	
Trowel							F		F				
Wooden block									F				
PROVIDED BY PARTICIPANTS													
Camera	F	F	F	F	F	F		L	L	L	L	L	L
Pocket knife									F				
GPS	F												
Hot pad / oven mitt									L				
Oven or lamp									L				
Newspaper									L				
Soap				L				L	L	L	L	L	
Watch or timer					F	F		L		L	L	L	
Weight (rock)		F											

FORM

MO DIRT CITIZEN SCIENCE PROJECT
SOIL SURVEY FORM

Annual, one-time data collection – Page 1

GROUP INFORMATION	
Group name *	
Participant's names *	
Institution (school, youth organization, etc.) *	
Contact information of survey leader * Name	
E-mail address	Phone no.
***These fields can be updated in the following surveys if necessary.**	

SURVEY SITE DESCRIPTION				
Date of survey (mm/dd/yyyy)	**Address (street number and name)**			
City	**County**	**State**	**Zip Code**	
Mean annual temperature (°C)	**Total annual precipitation (mm)**	**Elevation (m)**	**Slope (%)**	**Aspect (south, northwest, etc.)**

Replicates	**Geographical coordinates in decimal degrees**	
	Latitude	**Longitude**
1		
2*		
3*		
4*		
5*		

*** Only include these coordinates if you cannot leave the stakes in place due to management practices.**

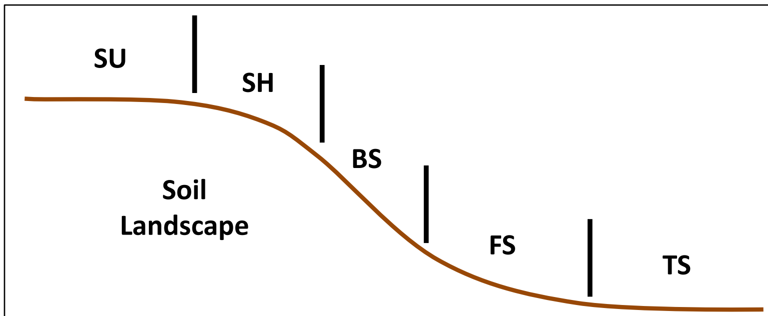
Map unit name and symbol: Visit the SoilWeb to find the information (http://casoilresource.lawr.ucdavis.edu/gmap/).

Map unit name	**Map unit symbol**

Annual, one time data collection – Page 2

Date of survey (mm/dd/yyyy)

SURVEY SITE DESCRIPTION continuation
Survey site landscape position (see diagram below).
Habitat type *(e.g., forest, woodland, prairie, grassland (grazing field, hay field, etc.), animal pasture or cropland (tillage, no-tillage).
If cropland include type of crop * (soy, corn, sorghum, alfalfa, etc.) **and cropping system** (rotation, cover crops, etc.)
Topography (e.g., hills, ridges, depressions, knolls, potholes, etc.).
Present land management * (e.g., logging, reforestation, flooding, pesticides, fertilizers, irrigation, prescribed burns, undisturbed, etc.).
Past management history (last 5 to 10 years) (e.g., logging, reforestation, flooding, pesticides, fertilizers, irrigation, prescribed burns, undisturbed, etc.).
***These fields can be updated in the following surveys if necessary.**



Hillslope cross-section depicting soil elements within the soil landscape. SU – Summit; SH – Shoulder Slope; BS – Backslope; FS – Footslope; TS – Toeslope/Floodplain.

Soil core variables data (up to 25 cm (10") depth)								
Potential soil layers	**Layer 1**		**Layer 2**		**Layer 3**		**Layer 4**	
Replicate	**Texture**	**Color**	**Texture**	**Color**	**Texture**	**Color**	**Texture**	**Color**
1								

Annual, one time data collection – Page 3

DATE OF SOIL SURVEY (mm/dd/yyyy)

Drawing of site: Aerial view of site showing replicates sites and location of landmarks (river, lake, road, etc.) and other features you think are important to include in the survey. Use colors to illustrate different features. Take a photo of your drawing and of the dominant habitat of the survey site to be used digitally (This is optional).

Scale 1 inch = ____________ ft (NA indicates sketch not to scale)

Monthly data collection – Page 4

(Make a photocopy of this page per survey *)

*** Fill only the fields that you need to update per survey.**

DATE OF SOIL SURVEY (mm/dd/yyyy)

UPDATES - GROUP INFORMATION	
Group name	
Participant's names	
Institution (school, youth organization, etc.)	
Contact information of survey leader Name	
E-mail address	Phone no.

UPDATES - SURVEY SITE DESCRIPTION
Habitat type (e.g., forest, woodland, prairie, grassland (grazing field, hay field, etc.), animal pasture or cropland (tillage, no-tillage).
If cropland include type of crop (soy, corn, sorghum, alfalfa, etc.) **and cropping system** (rotation, cover crops, etc.)
Signs of erosion
Present land management (e.g., logging, reforestation, flooding, pesticides, fertilizers, irrigation, prescribed burns, etc.).

Notes:

Monthly data collection – Page 5

(Make a photocopy of this page per survey)

DATE OF SOIL SURVEY (mm/dd/yyyy)

Temperatures and cloud cover					
Replicate No.	Air temperature (°C)	Soil temperature (C°)			Cloud cover (%)
		Surface (0 cm)	5 cm depth	10 cm depth	
1					
2					
3					
4					
5					

Soil respiration								
Time of data collection as hh:mm (00-23 hours: 00-59 minutes) (e.g. 13:45, 08:23) Color number by hour (h).								
	0 h	1 h	2 h	3 h	4 h	5 h	10 h	24 h
Time of data collection								
Color No.								
Interpretation of colors for CO_2-C emissions (lbs/acre/day) at 24 hours								
CO_2-C emissions (lbs/acre/day) at room temperature (Table 6 in protocol). *								
CO_2-C emissions (lbs/acre/day) at field soil temperature (Table 7 in protocol).								
* If the gel in the paddle changes color fast within the first five hours, follow the instructions in page 41 of protocol (Soils from natural habitats) to estimate the equivalent CO_2-C emissions after 24 hours into the test.								

Notes:

Monthly data collection – Page 6

(Make a photocopy of this page per survey)

DATE OF SOIL SURVEY (mm/dd/yyyy)

Calculations for bulk density, water content, and soil water-filled pore space (%WFPS)

	Sample before drying			Sample after drying			Volume of soil sample (G)
Explanation of calculations	A Weight of wet soil + bag (g)	B Weight of bag (g)	C Weight of wet soil (g) C = A - B	D Weight of dry soil + container (g)	E Weight of container (g)	F Weight of dry soil (g) F = D – E	Equals the interior volume of the metal ring ($\pi \times r^2 \times L$) (cm^3) *
Composite sample **							

Calculations for bulk density, water content, and soil water-filled pore space (%WFPS). Continuation.

Explanation of calculations	H Soil bulk density (g/cm^3) H = F / G *	I % Gravimetric soil water content I = [(C – F) / F] x 100	J % Volumetric soil water content J = I x H	K % Total soil porosity K = [1 – (H/2.65 g/cm^3)] x 100	L % Water-filled pores L = (J/K) x 100
	H = Weight of dry soil / Volume of soil sample	I = [(Weight of wet soil – Weight of dry soil) / Weight of dry soil] x 100	J = % Gravimetric soil water content x Soil bulk density	[1 – (Soil bulk density / Soil particle density)] x 100	(% Volumetric water content / % Total porosity) x 100
Composite sample **					

* These variables are calculated once a year when bulk density is collected. Use the values of G and H every month to calculate J, K, and L.

** Use a composite soil sample every month, except the month you collect soil in a ring to calculate bulk density.

Notes:

Twice a year data collection – Page 7

(Make a photocopy of this page per survey)

DATE OF SOIL SURVEY (mm/dd/yyyy)

Chemical soil properties							
Composite sample	**N**	**P**	**K**	**Composite sample**	**pH**	**Composite sample**	**Active carbon**
Values from color comparators				**pH number**		**Soil quality based on color chart**	
Equivalency in parts per million (Mg/Liter) based on table in protocol *				**pH category Alkaline – very Acid**		**Active carbon in pounds per acre (lbs/A) ****	
*** Use Table 9 in protocol to interpret the data.** **** Use Table 10 to interpret the data.**							

Organic Matter (%)	
After you send the organic matter sample for testing, the results will be sent to you. You should enter the value of % organic matter in the Data Portal.	

Notes:

CONTACT US

EPSCOR EDUCATION TEAM – MO DIRT

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http://modirt.missouriepscor.org

Sources

This soil health survey manual has been developed using sources from several institutions:

Cornell Soil Health – soilhealth.cals.cornell.edu

Department of Environmental Science and Technology, University of Maryland – www.ensp.umd.edu

European Geosciences Union – blogs.egu.eu?

FAO Soils Portal – www.fao.org/soils-portal/en

Luster Leaf ® – www.lusterleaf.com

Natural Resources Conservation Service (NRCS) - Soils – www.nrcs.usda.gov/wps/portal/nrcs/site/soils/home

Nature Education – www.nature.com/nature_education

Nebraska Agricultural Experiment Station – ard.unl.edu

Soil Health Assessment Center – cafnr.missouri.edu/soil-health

Soil Quality for Environmental Health – soilquality.org/home.html

Soil Science Society of America – www.soils.org

Solvita ® – solvita.com

The Globe Program – www.globe.gov

The Ohio State University Extension – extension.osu.edu

US Environmental Protection Agency – www3.epa.gov

APPENDICES

Appendix 1. Tables of unit conversions.

Feet to meters conversion table.

Feet	Meters	Feet	Meters	Feet	Meters	Feet	Meters
		20	6.09	50	15.24	80	24.38
0.1	0.030	21	6.40	51	15.54	81	24.68
0.2	0.060	22	6.70	52	15.84	82	24.99
0.3	0.091	23	7.01	53	16.15	83	25.29
0.4	0.121	24	7.31	54	16.45	84	25.60
0.5	0.152	25	7.62	55	16.76	85	25.90
0.6	0.182	26	7.92	56	17.06	86	26.21
0.7	0.213	27	8.22	57	17.37	87	26.51
0.8	0.243	28	8.53	58	17.67	88	26.82
0.9	0.274	29	8.83	59	17.98	89	27.12
1	0.30	30	9.14	60	18.28	90	27.43
2	0.60	31	9.44	61	18.59	91	27.73
3	0.91	32	9.75	62	18.89	92	28.04
4	1.21	33	10.05	63	19.20	93	28.34
5	1.52	34	10.36	64	19.50	94	28.65
6	1.82	35	10.66	65	19.81	95	28.95
7	2.13	36	10.97	66	20.11	96	29.26
8	2.43	37	11.27	67	20.42	97	29.56
9	2.74	38	11.58	68	20.72	98	29.87
10	3.04	39	11.88	69	21.03	99	30.17
11	3.35	40	12.19	70	21.33	100	30.4
12	3.65	41	12.49	71	21.64	200	60.9
13	3.96	42	12.80	72	21.94	300	91.4
14	4.26	43	13.10	73	22.25	400	121.9
15	4.57	44	13.41	74	22.55	500	152.4
16	4.87	45	13.71	75	22.86	600	182.8
17	5.18	46	14.02	76	23.16	700	213.3
18	5.48	47	14.32	77	23.46	800	243.8
19	5.79	48	14.63	78	23.77	900	274.3
		49	14.93	79	24.07	1000	304.8

Source: Southeastern Printing

Inches to centimeters conversion table.

Inches	Centimeters
0.1	0.254
0.2	0.508
0.3	0.762
0.4	1.016
0.5	1.27
0.6	1.524
0.7	1.778
0.8	2.032
0.9	2.286
1	2.54
2	5.08
3	7.62
4	10.16
5	12.7
6	15.24
7	17.78
8	20.32
9	22.86
10	25.4
11	27.94
12	30.48
13	33.02
14	35.56
15	38.1
16	40.64
17	43.18
18	45.72
19	48.26

Inches	Centimeters
20	50.8
21	53.34
22	55.88
23	58.42
24	60.96
25	63.5
26	66.04
27	68.58
28	71.12
29	73.66
30	76.2
31	78.74
32	81.28
33	83.82
34	86.36
35	88.9
36	91.44
37	93.98
38	96.52
39	99.06
40	101.6
41	104.14
42	106.68
43	109.22
44	111.76
45	114.3
46	116.84
47	119.38
48	121.92
49	124.46

Inches	Centimeters
50	127
51	129.54
52	132.08
53	134.62
54	137.16
55	139.7
56	142.24
57	144.78
58	147.32
59	149.86
60	152.4
61	154.94
62	157.48
63	160.02
64	162.56
65	165.1
66	167.64
67	170.18
68	172.72
69	175.26
70	177.8
71	180.34
72	182.88
73	185.42
74	187.96
75	190.5
76	193.04
77	195.58
78	198.12
79	200.66

Inches	Centimeters
80	203.2
81	205.74
82	208.28
83	210.82
84	213.36
85	215.9
86	218.44
87	220.98
88	223.52
89	226.06
90	228.6
91	231.14
92	233.68
93	236.22
94	238.76
95	241.3
96	243.84
97	246.38
98	248.92
99	251.46
100	254
200	508
300	762
400	1016
500	1270
600	1524
700	1778
800	2032
900	2286
1000	2540

Source: Southeastern Printing

Appendix 2. Table of temperature conversions.

Celsius (°C)	Fahrenheit (°F)	Description
-273.15 °C	-459.67 °F	absolute zero temperature
-50 °C	-58.0 °F	
-40 °C	-40.0 °F	
-30 °C	-22.0 °F	
-20 °C	-4.0 °F	
-10 °C	14.0 °F	
-9 °C	15.8 °F	
-8 °C	17.6 °F	
-7 °C	19.4 °F	
-6 °C	21.2 °F	
-5 °C	23.0 °F	
-4 °C	24.8 °F	
-3 °C	26.6 °F	
-2 °C	28.4 °F	
-1 °C	30.2 °F	
0 °C	32.0 °F	freezing/melting point of water
1 °C	33.8 °F	
2 °C	35.6 °F	
3 °C	37.4 °F	
4 °C	39.2 °F	
5 °C	41.0 °F	
6 °C	42.8 °F	
7 °C	44.6 °F	
8 °C	46.4 °F	
9 °C	48.2 °F	
10 °C	50.0 °F	
20 °C	68.0 °F	

Celsius (°C)	Fahrenheit (°F)	Description
21 °C	69.8 °F	room temperature
30 °C	86.0 °F	
37 °C	98.6 °F	average body temperature
40 °C	104.0 °F	
50 °C	122.0 °F	
60 °C	140.0 °F	
70 °C	158.0 °F	
80 °C	176.0 °F	
90 °C	194.0 °F	
100 °C	212.0 °F	boiling point of water
200 °C	392.0 °F	
300 °C	572.0 °F	
400 °C	752.0 °F	
500 °C	932.0 °F	
600 °C	1112.0 °F	
700 °C	1292.0 °F	
800 °C	1472.0 °F	
900 °C	1652.0 °F	
1000 °C	1832.0 °F	

Source: Metric Conversions (www.metric-conversions.org/)

Appendix 3. Safety data sheet for potassium permanganate (0.2 *M* solution)

SIGMA-ALDRICH sigma-aldrich.com

SAFETY DATA SHEET

Version 3.5
Revision Date 03/04/2015
Print Date 11/02/2015

1. PRODUCT AND COMPANY IDENTIFICATION

1.1 Product identifiers

Product name	:	Potassium permanganate solution
Product Number	:	319414
Brand	:	Fluka

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses	:	Laboratory chemicals, Manufacture of substances

1.3 Details of the supplier of the safety data sheet

Company	:	Sigma-Aldrich 3050 Spruce Street SAINT LOUIS MO 63103 USA
Telephone	:	+1 800-325-5832
Fax	:	+1 800-325-5052

1.4 Emergency telephone number

Emergency Phone #	:	(314) 776-6555

2. HAZARDS IDENTIFICATION

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)
Skin irritation (Category 2), H315
Serious eye damage (Category 1), H318
Acute aquatic toxicity (Category 1), H400
Chronic aquatic toxicity (Category 1), H410

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram

Signal word	Danger
Hazard statement(s)	
H315	Causes skin irritation.
H318	Causes serious eye damage.
H410	Very toxic to aquatic life with long lasting effects.
Precautionary statement(s)	
P264	Wash skin thoroughly after handling.
P273	Avoid release to the environment.
P280	Wear eye protection/ face protection.
P280	Wear protective gloves.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P305 + P351 + P338 + P310	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor/ physician.

P332 + P313	If skin irritation occurs: Get medical advice/ attention.
P362	Take off contaminated clothing and wash before reuse.
P391	Collect spillage.
P501	Dispose of contents/ container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

3. COMPOSITION/INFORMATION ON INGREDIENTS

3.2 Mixtures

Formula : $KMnO_4$

Molecular weight : 158.03 g/mol

Hazardous components

Component		Classification	Concentration
Potassium permanganate			
CAS-No.	7722-64-7	Ox. Sol. 2; Acute Tox. 4; Skin Corr. 1B; Eye Dam. 1; Aquatic Acute 1; Aquatic Chronic 1; H272, H302, H314, H410	>= 1 - < 5 %
EC-No.	231-760-3		
Index-No.	025-002-00-9		

For the full text of the H-Statements mentioned in this Section, see Section 16.

4. FIRST AID MEASURES

4.1 Description of first aid measures

General advice
Consult a physician. Show this safety data sheet to the doctor in attendance. Move out of dangerous area.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Consult a physician.

In case of eye contact
Rinse thoroughly with plenty of water for at least 15 minutes and consult a physician. Continue rinsing eyes during transport to hospital.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

5. FIREFIGHTING MEASURES

5.1 Extinguishing media

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

5.2 Special hazards arising from the substance or mixture
Potassium oxides, Manganese/manganese oxides

5.3 Advice for firefighters
Wear self-contained breathing apparatus for firefighting if necessary.

5.4 Further information
No data available

6. ACCIDENTAL RELEASE MEASURES

6.1 Personal precautions, protective equipment and emergency procedures

Use personal protective equipment. Avoid breathing vapours, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas.
For personal protection see section 8.

6.2 Environmental precautions

Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

6.3 Methods and materials for containment and cleaning up

Soak up with inert absorbent material and dispose of as hazardous waste. Keep in suitable, closed containers for disposal.

6.4 Reference to other sections

For disposal see section 13.

7. HANDLING AND STORAGE

7.1 Precautions for safe handling

Avoid contact with skin and eyes. Avoid inhalation of vapour or mist.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities

Keep container tightly closed in a dry and well-ventilated place. Containers which are opened must be carefully resealed and kept upright to prevent leakage.
Storage class (TRGS 510): Non Combustible Liquids

7.3 Specific end use(s)

Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

8.1 Control parameters

Components with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
Potassium permanganate	7722-64-7	C	5.000000 mg/m3	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
	Remarks	Ceiling limit is to be determined from breathing-zone air samples.		
		TWA	0.200000 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Central Nervous System impairment Adopted values or notations enclosed are those for which changes are proposed in the NIC See Notice of Intended Changes (NIC) varies		
		TWA	1.000000 mg/m3	USA. NIOSH Recommended Exposure Limits
		ST	3.000000 mg/m3	USA. NIOSH Recommended Exposure Limits
		TWA	0.100000 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Central Nervous System impairment 2014 Adoption varies		
		TWA	0.020000 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Central Nervous System impairment 2014 Adoption		

		varies		
		C	5 mg/m3	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
		Ceiling limit is to be determined from breathing-zone air samples.		
		TWA	0.1 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Central Nervous System impairment varies		
		TWA	0.02 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
		Central Nervous System impairment varies		
		TWA	1 mg/m3	USA. NIOSH Recommended Exposure Limits
		ST	3 mg/m3	USA. NIOSH Recommended Exposure Limits

8.2 Exposure controls

Appropriate engineering controls
Handle in accordance with good industrial hygiene and safety practice. Wash hands before breaks and at the end of workday.

Personal protective equipment

Eye/face protection
Tightly fitting safety goggles. Faceshield (8-inch minimum). Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Body Protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face respirator with multi-purpose combination (US) or type ABEK (EN 14387) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Control of environmental exposure
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

9. PHYSICAL AND CHEMICAL PROPERTIES

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: clear, liquid Colour: dark violet
b)	Odour	No data available
c)	Odour Threshold	No data available
d)	pH	No data available
e)	Melting point/freezing point	No data available
f)	Initial boiling point and boiling range	No data available

g)	Flash point	Not applicable
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	No data available
k)	Vapour pressure	No data available
l)	Vapour density	No data available
m)	Relative density	No data available
n)	Water solubility	No data available
o)	Partition coefficient: n-octanol/water	No data available
p)	Auto-ignition temperature	No data available
q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	No data available
t)	Oxidizing properties	No data available

9.2 Other safety information
No data available

10. STABILITY AND REACTIVITY

10.1 Reactivity
No data available

10.2 Chemical stability
Stable under recommended storage conditions.

10.3 Possibility of hazardous reactions
No data available

10.4 Conditions to avoid
No data available

10.5 Incompatible materials
Zinc, Powdered metals, Peroxides, Copper, Strong reducing agents

10.6 Hazardous decomposition products
Other decomposition products - No data available
In the event of fire: see section 5

11. TOXICOLOGICAL INFORMATION

11.1 Information on toxicological effects

Acute toxicity
Inhalation: No data available

Dermal: No data available

No data available

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitisation
No data available

Germ cell mutagenicity
No data available

Carcinogenicity

IARC:	No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity
No data available
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Additional Information
RTECS: Not available

Men exposed to manganese dusts showed a decrease in fertility. Chronic manganese poisoning primarily involves the central nervous system. Early symptoms include languor, sleepiness and weakness in the legs. A stolid mask-like appearance of the face, emotional disturbances such as uncontrollable laughter and a spastic gait with tendency to fall in walking are findings in more advanced cases. High incidence of pneumonia has been found in workers exposed to the dust or fume of some manganese compounds., To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

12. ECOLOGICAL INFORMATION

12.1 Toxicity
No data available

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Other adverse effects
An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.
Very toxic to aquatic life with long lasting effects.

13. DISPOSAL CONSIDERATIONS

13.1 Waste treatment methods

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
Not dangerous goods

IMDG
UN number: 3082 Class: 9 Packing group: III EMS-No: F-A, S-F
Proper shipping name: ENVIRONMENTALLY HAZARDOUS SUBSTANCE, LIQUID, N.O.S. (Potassium permanganate)
Marine pollutant:yes

IATA
UN number: 3082 Class: 9 Packing group: III
Proper shipping name: Environmentally hazardous substance, liquid, n.o.s. (Potassium permanganate)

Further information
EHS-Mark required (ADR 2.2.9.1.10, IMDG code 2.10.3) for single packagings and combination packagings containing inner packagings with Dangerous Goods > 5L for liquids or > 5kg for solids.

15. REGULATORY INFORMATION

SARA 302 Components
No chemicals in this material are subject to the reporting requirements of SARA Title III, Section 302.

SARA 313 Components
The following components are subject to reporting levels established by SARA Title III, Section 313:

	CAS-No.	Revision Date
Potassium permanganate	7722-64-7	1993-04-24

SARA 311/312 Hazards
Acute Health Hazard

Massachusetts Right To Know Components

	CAS-No.	Revision Date
Potassium permanganate	7722-64-7	1993-04-24

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Potassium permanganate	7722-64-7	1993-04-24

New Jersey Right To Know Components

	CAS-No.	Revision Date
Water	7732-18-5	
Potassium permanganate	7722-64-7	1993-04-24

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

16. OTHER INFORMATION

Full text of H-Statements referred to under sections 2 and 3.

Acute Tox.	Acute toxicity
Aquatic Acute	Acute aquatic toxicity
Aquatic Chronic	Chronic aquatic toxicity
Eye Dam.	Serious eye damage
H272	May intensify fire; oxidiser.
H302	Harmful if swallowed.
H314	Causes severe skin burns and eye damage.
H315	Causes skin irritation.
H318	Causes serious eye damage.
H400	Very toxic to aquatic life.
H410	Very toxic to aquatic life with long lasting effects.
Ox. Sol.	Oxidizing solids
Skin Corr.	Skin corrosion

HMIS Rating

Health hazard:	3
Chronic Health Hazard:	
Flammability:	0
Physical Hazard	3

NFPA Rating

Health hazard:	3
Fire Hazard:	0
Reactivity Hazard:	0

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Preparation Information

Sigma-Aldrich Corporation
Product Safety – Americas Region
1-800-521-8956

Version: 3.5 Revision Date: 03/04/2015 Print Date: 11/02/2015