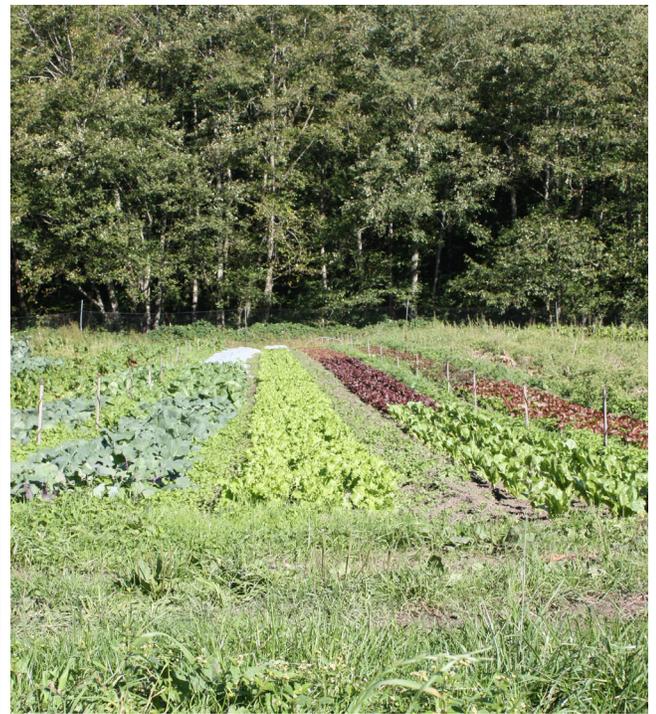


Soil Testing: A Guide for Farms with Diverse Vegetable Crops

WASHINGTON STATE UNIVERSITY EXTENSION • EM050E



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Soil Testing: A Management Tool

Introduction

Soil analysis can guide farmers and gardeners in making soil amendment and soil management decisions. Making soil sampling an annual event will allow for tracking management practices and influencing future soil amendment decisions. This fact sheet presents a comprehensive, yet affordable, procedure for implementing an annual soil-testing program for farms with diverse vegetable crops. The reader will learn when to sample, where to sample, how to take a sample, and finally how to use sample results to improve farm management.

The Importance of Soil Testing

Soil testing results can indicate nutrient deficiencies or excesses, nutrient-holding capacity, organic matter content, and soil alkalinity or acidity. The value and reliability of this information depends on how a sample is taken and what area of the farm the sample represents. Trying to represent too large an area with one sample is counterproductive, especially if crops with different nutrient requirements will be planted within the same area.

If soil testing is done carefully and consistently over several years, soil test data can be used to determine the timing and amounts of fertilizer, compost, manure, lime, or other amendments aimed at improving crop response. Soil testing can also be used to evaluate soil improvement strategies, such as cover cropping. Finally, a soil test can be used to evaluate fertilizer efficiency.

The Challenges to Implementing a Soil-Testing Program

The variability in soil properties across the farm creates a challenge for farmers who want to describe their farm's soil properties. Soils vary because of geological changes over time and because of landscape position, vegetation, soil organisms, and past management. In addition to the differences in soil

properties, the diversity of farm plantings also makes it difficult to describe and manage soil. Each contiguous area that is planted, fertilized, and otherwise managed together can be seen as a management zone. Farms with a wide variety of crops tend to have many management zones.

Soil-Testing Methods

Divide The Farm by Landscape Position, Soil Type, and Management History

Soil properties, such as texture, drainage, and topography, will vary across the farm and even within a field (Collins et al. 2011). For example, soil in one field may be "heavier" at the western end, indicating greater clay content toward the west and less toward the east. In another example, low areas in a field may drain poorly and produce less than other areas. Management history also has an effect. For instance, an area formerly used as pasture or a feedlot will likely have different properties and soil management needs than the rest of the field. Sometimes, an area may produce poorly, although no cause is apparent. Soil analysis may reveal the reason for this poor production.

A practical first step in soil testing is to create a detailed map of the farm that includes landscape position (including boundaries and elevations), soil type, and management history. To do this, begin with an aerial photograph of the farm, and then add further details to it. If necessary, use a topographical map to delineate hilltops, slopes, bottom lands, and other landscape features (Figure 1) (U.S. Geological Survey 2011).

Consult the Natural Resources Conservation Service (NRCS) soil maps, available through the Web Soil Survey (NRCS 2011), to find information on the variation of soil types across the farm (Figure 2).

These maps typically do not provide enough detail to capture changes in soil type, so observing soil color, texture (sand, silt, and clay content), and yield history can complement the soil survey and provide



Figure 1. Aerial photograph of landscape position and elevation.

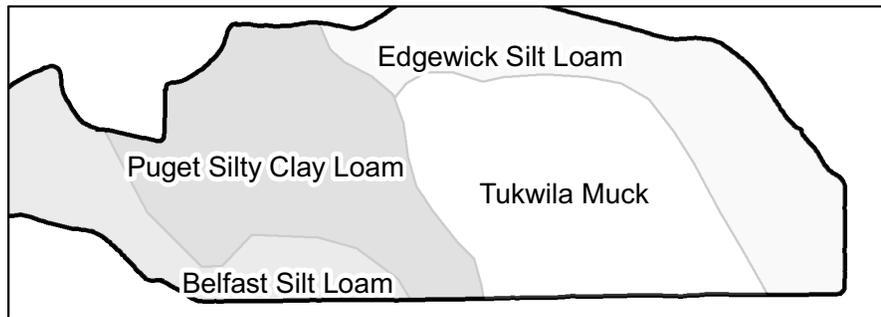


Figure 2. Map of soil type variation across the farm.

more detail on soil types. Next, outline the approximate boundaries of known or suspected areas that were used differently in the past, such as old roads, home sites, or orchards (Figure 3).

A map that combines these different layers can be used to develop a soil-sampling plan (Figure 4). Regardless of which sample plan is chosen, differing soil types should never be combined into the same sample.

Describe Soil by Implementing a Sampling Method

Soil sampling can enhance understanding of how soil type and historical management might influ-

ence plant productivity. Just as importantly, recent management decisions can be evaluated through consistent and well planned use of soil sampling. Three basic sampling strategies can be used to further describe different soil types: composite (Figure 5), grid (Figure 6), and management zone (Figure 7) (Eash and Lamb 2002).

Composite sampling is the least intensive method and involves pulling soil cores randomly across an area delimited by soil type. About 15 cores are composited into one sample and then sent for analysis.

Grid sampling involves tracing a grid over the farm to divide it into equally sized cells. Each cell is then characterized by compositing soil from the entire

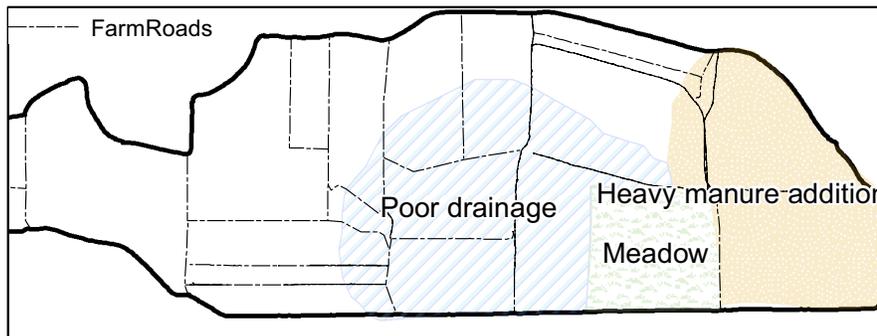


Figure 3. Historical management and seasonal flooding based on farmer knowledge.

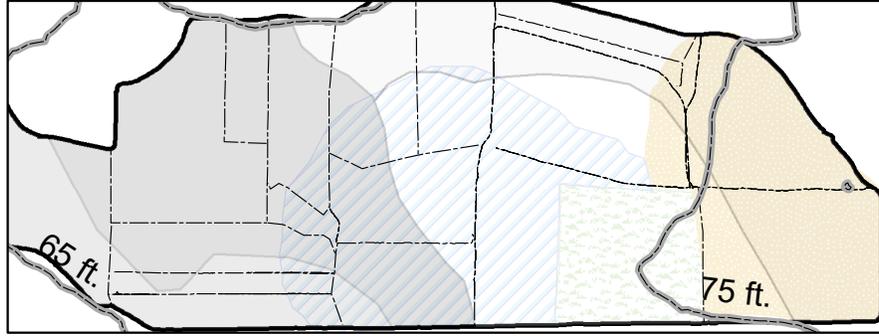


Figure 4. Layered map (includes landscape position, elevation, soil type, historical soil management, and seasonal flooding based on farmer knowledge).

cell (grid-cell sampling) or by compositing soil from a smaller area in the middle of the cell (grid-point sampling). Generally, a geographical positioning system (GPS) unit is used in order to return to the same place each year. The grid-sampling method is extremely powerful in visualizing spatial variability in soil properties. The grid method is more robust (but more expensive) as the size of each cell decreases (i.e., when more samples are taken per acre).

Grid sampling a soil's physical properties can also help determine soil type. For example, a map of soil texture for an entire farm can be developed using grid sampling. Because texture is not affected by soil management practices, such a map would only need to be created once. Electrical conductivity is another soil property that is commonly sampled using a grid. This sampling is often done using an all-terrain vehicle, geographical positioning system,

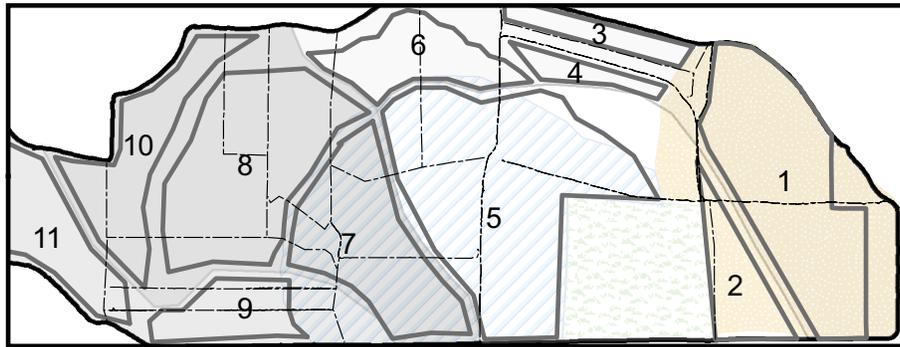


Figure 5. Composite sampling. Areas with similar soil type are combined to form a sample.

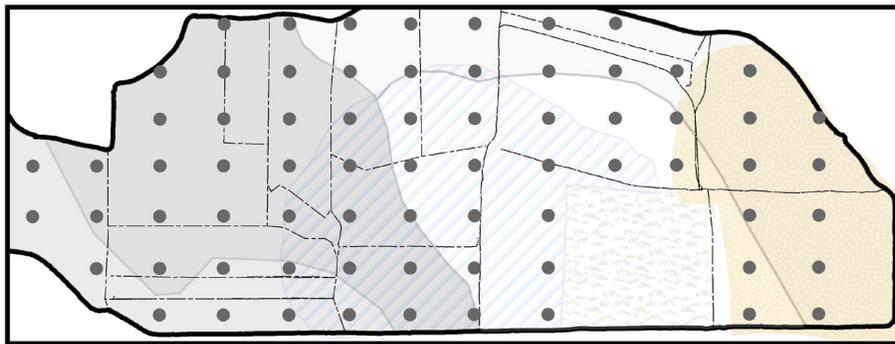


Figure 6. Grid sampling. Samples are taken at points across a grid by compositing soil from a small area (dark circles). Each sample is analyzed separately.

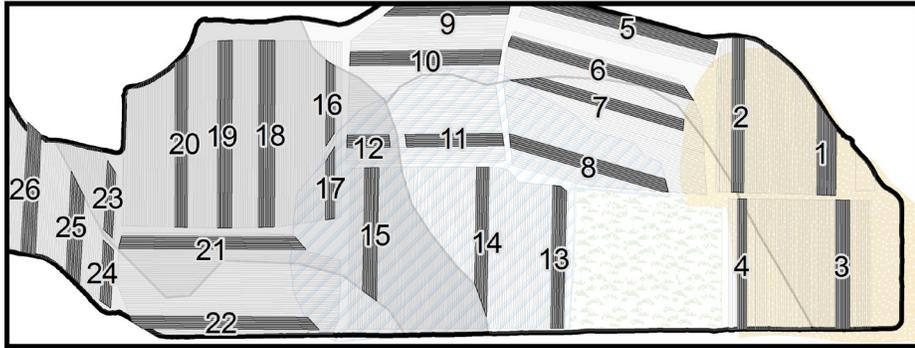


Figure 7. Management zone sampling. Soil within a management zone and within a soil type is composited for a sample. Representative management zones are chosen for sampling.

and mounted sensor. Electrical conductivity can be used to effectively estimate soil texture and other soil properties. Aerial photography, while not a type of grid sampling, can also reveal the spatial patterns of soil properties. When high resolution digital photographs are taken of bare and dry soil, they can be used to estimate the amount of soil organic matter. The information gathered through intensive grid sampling or aerial photography can be used to update soil-type maps and influence the location of management zones.

Management zone sampling involves accounting for both the soil type and the scale and layout of farm operations. A management zone is a contiguous area that is planted, fertilized, and otherwise managed together. A soil-sampling strategy that is based on management zones combines some aspects of composite and grid sampling. The farm is first divided into management zones that form a grid, and a composite sample is taken from each zone.

Management zone sizes may range from less than 1,000 ft² up to many acres and can vary within the same farm or garden. A management zone can even be as narrow as the equipment used to apply amendments, for example, tractor width.

The map of management zones should be layered over a detailed map of topography, soil type, and soil management history. Ideally, an individual management zone should not cross topography, soil type, or areas with a notably different management history.

Farms growing a diversity of vegetables tend to have many management zones, reflecting their wide variety of crops. A small farm of 1 to 10 acres that provides vegetables to customers on a weekly basis may grow 20 to 100 or more different crops. Some crops may occupy only 1 or 2 beds, while other crops, fallowed areas, or cover crops may occupy large swaths. Dividing the farm into smaller management zones,

such as 2 beds, would accommodate most of the planting situations desired and simplify planning considerably.

Characterize Farm Variability Using Reference Areas

Identify Sampling Locations

Dividing a farm into as many management zones as necessary for crop planning and nutrient management is a good strategy. But as the number of management zones increases—to as many as 200 on some farms—sampling each zone annually becomes unrealistic. However, it is not necessary to sample each management zone every year, and, in fact, many management zones may never have to be sampled. An effective alternative is to sample a few *reference areas*, which are representative management zones from each field or soil type. For example, in a 10-acre field with 100 beds, 1 or 2 management zones of 10 beds each could be sampled. While the data gathered will cover less of the farm than whole-field samples, the data will be more meaningful and can be more usefully applied to make management decisions. This is because specific data about a smaller area are better than general data about a larger area (Mallarino and Wittry 2001).

For the first few years, farmers may want to choose the same management zones for annual sampling. This allows them to track soil changes as management zones pass through a rotation or a multi-year liming program, for example. The location of sampled (i.e., reference) areas should be recorded by one or more methods. If beds are located in the same place each year—a practice that can simplify management—then beds within each field can be numbered. The individual bed or group of beds sampled should be recorded. A GPS unit could also be used to

mark the area. Finally, a good farm map and detailed field maps can be used to identify and mark locations.

Extrapolate Data to Areas Where Samples Were Not Taken

Sampled management zones can be used as reference areas for adjacent zones. This strategy should be coupled with the use of a soil-type map, and care should be taken to sample management zones within each soil type. This approach is similar to grid-point sampling for larger farms. Soil composited from a “point” (500–1500 ft²) is used to interpolate a map for areas not sampled and guide the use of amendments on land for which there is no specific data (Mallarino and Wittry 2001). For example, depending on the uniformity or variability of soil within a field, some amendments (e.g., lime, compost, or manure) might be applied evenly to all management zones in a field. If a pH or organic matter gradient is discovered, then the amount of lime, compost, or manure could be gradually increased or decreased across a field. Figure 8 shows the management zone

approach to soil sampling used in a few fields of differently sized farms.

Farm #1 is a 400-acre farm and 2 fields that constitute about 20 acres are shown. Farm #2 is a 6-acre farm and 3 fields that constitute about 3.7 acres are shown. Each management zone on Farm #1 is about 1 acre, while each management zone on Farm #2 is about 0.034 acres (1500 ft²). The shaded beds show the reference areas that were sampled, and the numbered circles represent individual soil cores that were combined to make a single sample. Reference areas were spaced to provide insight into spatial patterns in soil properties. Data from these reference areas were then used to guide management practices in those areas and in adjacent and nearby management zones.

Determine The Number of Samples to Be Taken

Enough samples should be taken to represent major differences in soil properties found across the farm. For example, if there is a known gradient in soil texture or organic matter across a field, then

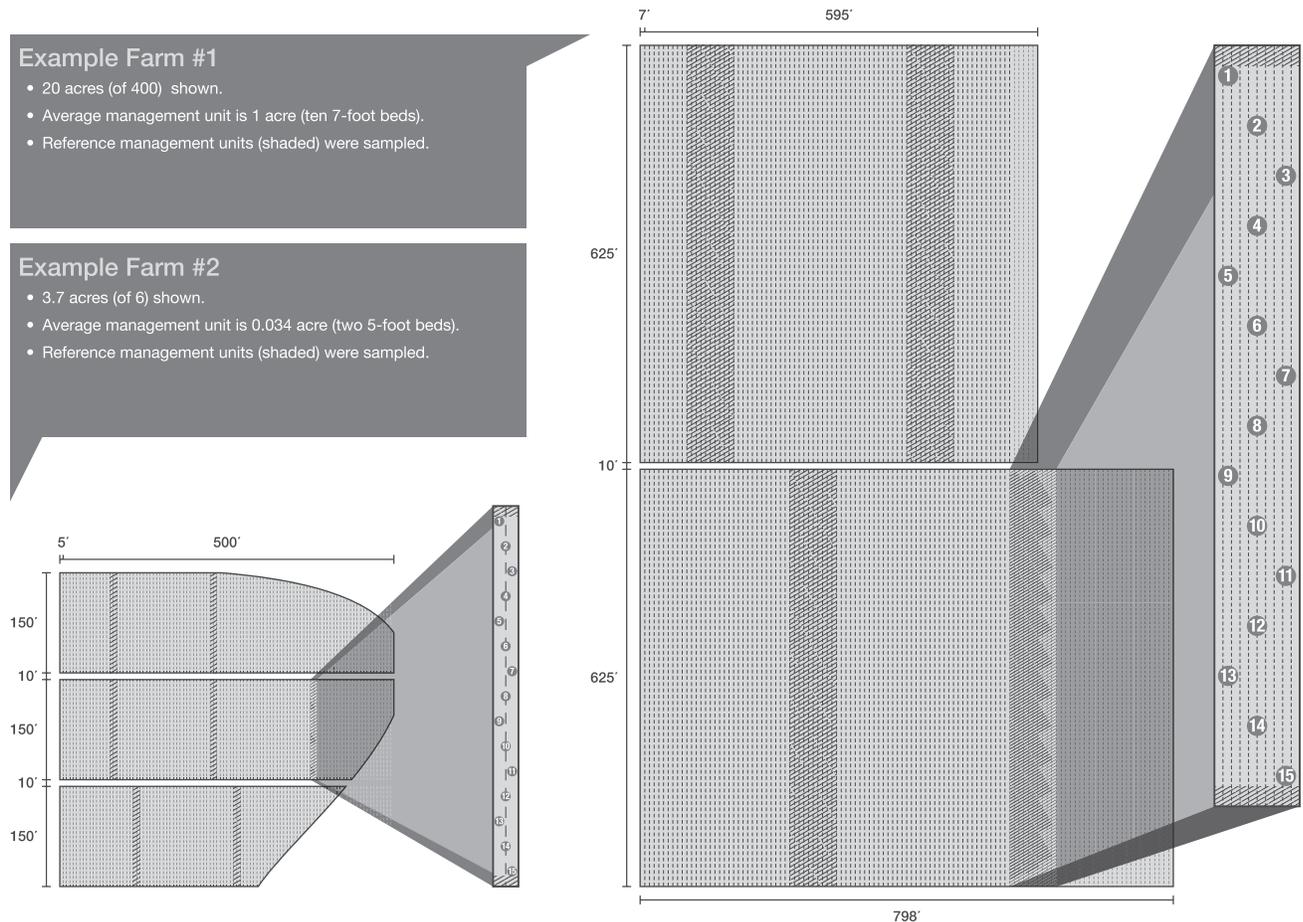


Figure 8. Soil management zone approach used on farms of varying size.

samples should be spaced to capture this variability. More samples will provide better detail for making soil management decisions. However, soil sampling and analysis cost time and money, so soil sampling should be carefully considered and planned. Figure 8 shows four reference areas for 20 acres of a 400-acre farm (Farm #1), and seven reference areas for 3.7 acres of a 6-acre farm (Farm #2). This sampling intensity equates to 80 samples for Farm #1 and 11 for all of Farm #2. These reference areas could be sampled annually or biannually, with half being sampled every other year, for example. Additional reference areas could be added if crop growth problems were identified in other areas.

When to Perform Soil Sampling

Soil samples for basic soil nutrient analysis (organic matter, phosphorus, potassium, magnesium, calcium, sulfate-sulfur, pH) and micronutrient analysis (boron, copper, iron, zinc) may be taken in the spring or fall. In dryer climates, a pre-plant spring sampling may make the most sense, since farmers are typically gearing up for the season. However, in maritime climates with significant winter rains and dryer summers, such as Oregon and Washington west of the Cascade Mountains, there is substantial added benefit to sampling between September 15th and October 15th (Sullivan and Cogger 2003). While this time period is a busy one, the nitrate-nitrogen information gained from these fall soil samples is useful. A fall nitrate test is called a “report card nitrate test” because it indicates how closely crop nitrogen (N) uptake has been matched with nitrogen supply. High (> 20 ppm) or excessive soil nitrate content in the fall indicates that too much N fertilizer or N-rich amendment was applied in the prior season.

Nitrate is highly soluble and does not attach to soil particles or organic matter in large amounts. So in regions with heavy winter rains, nitrate will leach into groundwater, which represents a financial loss and possible loss of water quality. Throughout spring and summer, the nitrate number is very dynamic, making it difficult to obtain reliable data. Consequently, early fall is the best time of year to

obtain reliable and consistent nitrogen information from soil in these areas.

The other soil nutrients are not so dynamic, so a spring or late fall sample will provide sufficient data. However, because of the environmental and economic importance of nitrogen, a report-card N test in early fall is the preferred sample timing for western Washington. Since the data are taken in the fall, it will not help for the current year’s fertilizer applications, but over several years, this information can be used to refine N applications and match them to crop requirements. Guidelines for interpreting nitrate levels from a fall nitrate test are given in Table 1.

How to Obtain a Soil Sample

A soil sample from a reference area should be composed of many subsamples taken within the area. Multiple subsamples provide a more accurate picture of the entire area and prevent an irregular area from skewing the results. Irregular areas can be caused by an uneven application of fertilizer or other amendment or by underlying soil variation. Fifteen is the minimum number of subsamples that should be taken but more than 30 will not greatly improve the results. Use clean, non-galvanized tools and containers for taking samples. Subsamples should be collected together in a clean bucket. The combined subsamples should provide enough soil for the analyses needed, usually 2 to 3 cups. Figure 9 shows a typical pattern for sampling a reference area, with 15 subsamples taken (see numbered circles).

Very different landscape positions should be split into separate management zones for sampling. However, if a depression or swale runs across the management zone and accounts for only a small percentage of the sample area, it should not be included in the sample. In other words, avoid non-representative areas if they are a small component of the zone, or split them off into separate management zones if they account for a large component.

Choose a soil depth that represents the nutrient distribution and rooting depth of plants. In culti-

Table 1. Post-harvest nitrate-nitrogen values and “report card” assessments (Sullivan and Cogger 2003).

Nitrate-N in surface foot (ppm)	Approximate nitrate-N in surface foot (lb/acre)*	Assessment
<10	<35	Low
10–20	35–70	Medium
20–30	70–105	High
>30	>105	Excessive

*Assumes 1 acre of soil at a depth of 1 foot weighs 3,500,000 pounds.

vated systems, plowing and tilling will have mixed previous amendment applications. “Tillage depth” is a common depth used for sampling. This depth can vary from 6 to 12 inches and because most plant roots are found in the tilled zone, the nutrient availability here is likely to have the greatest affect on plant growth. For a more detailed discussion of how nutrient concentrations change with depth, as well as when to sample deeper than 1 foot, or special considerations for sampling after fertilizer has been banded (applied only in the planting row), see University of Idaho Bulletin 704 (Mahler and Tindall 1998).

Each location can be sampled using a narrow-bladed shovel (spade) or a soil probe. A soil probe makes gathering subsamples much easier. If a soil probe is used, push the probe to the depth that was chosen for the sample (probably 6 to 12 inches for a tilled field). It is important to be consistent with each subsample and to note the depth of each sample when completing the sample submission forms. Some soil compaction is not uncommon as the probe is pushed into the soil (Figure 10).

If soil in the probe represents less than three-quarters of the desired depth, it is good practice to discard that subsample and obtain another one close by. Rocky or compacted soil can be a challenge to sample and may require a shallower sample or the use of a special hammer probe.

Sampling with a spade or shovel requires more time, but a perfectly good sample can be taken. To obtain a 12-inch-deep sample, start by digging a hole approximately 8 inches in diameter to a depth of 1 foot. Then, use the spade to slice off about a 1-inch-thick wedge of soil at a depth of 1 foot. Carefully pull the wedge up to the surface, balancing it on the spade

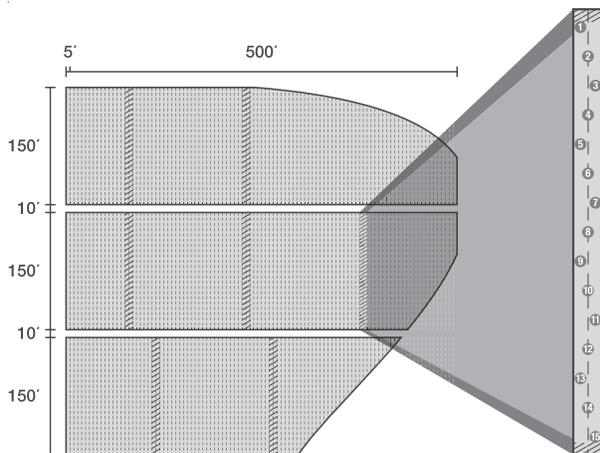


Figure 9. Typical pattern for sampling a reference area.

(Figure 10). Use a knife to cut a 1-inch-wide segment that runs from the top of the spade to the bottom. The resulting 1 inch x 1 inch x 12 inch segment can be dropped into the sample bucket before moving on to obtain the next subsample.

After collection, samples should be handled carefully. Ask the soil lab how they prefer to receive the sample (e.g., fresh or dried) and how much soil they require. Some labs encourage growers to keep the sample refrigerated and then send it overnight to the lab. Another alternative is to air dry the samples on the day of sampling by spreading soil in a thin layer in trays or on paper or plastic. Samples should be mixed well by hand in the field and then a representative sample bagged for the lab. Make sure to send as much soil as the lab requires, and complete sample submission forms carefully and thoroughly.

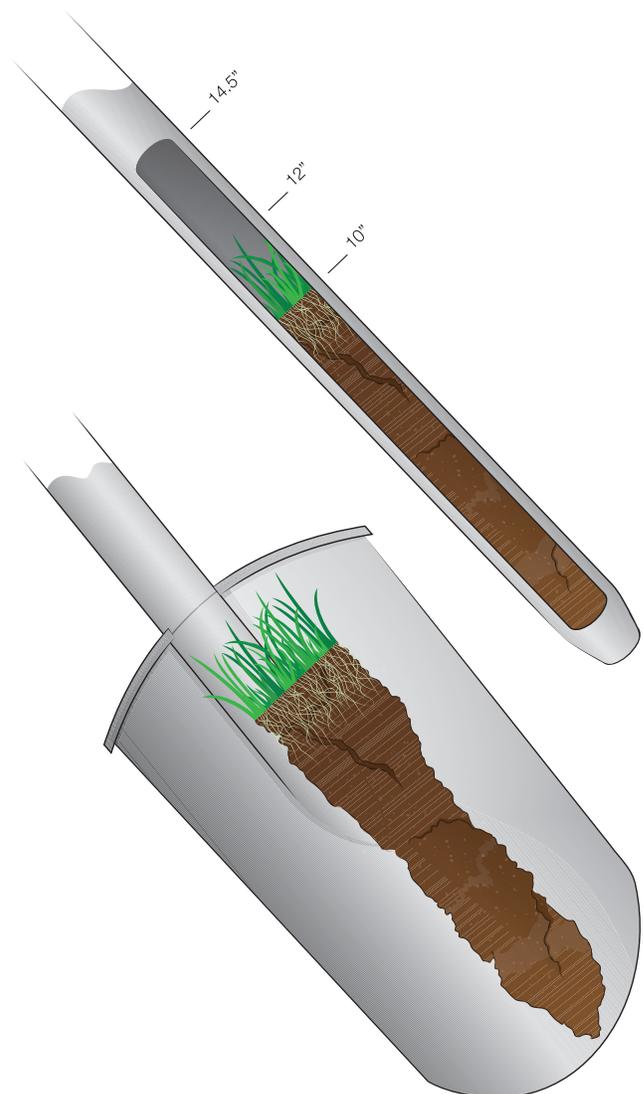


Figure 10. Taking a soil core sample using a soil probe (top). Taking a soil core sample using a spade (bottom).

How to Track and Use Data

Perhaps the most powerful aspect of sampling distinct management zones is the ability to revisit these zones year after year. Changes in soils and crop yield in these zones can be linked, over time, to management decisions. Carefully tracking amendments, crops, crop growth, and soil test data (using a notebook, spreadsheet, or database) will allow for site-specific conclusions.

For example, a particular field may have 100 5-foot-wide beds, and the field may be divided into 50 management zones of 2 beds each. Two management zones (beds 21-22 and beds 79-80) are sampled in the fall. Lime requirements are reported as 4,000 lb/acre and 6,000 lb/acre, respectively, and organic matter was found to be 3% and 4%, respectively. Working with these data, farmers could increase lime application from 4,000 lb/acre to 6,000 lb/acre as they moved from bed 23 to bed 78. Similarly, if compost or manure is being broadcast to increase organic matter, it could be spread more heavily on soil near bed 22 and decreased across the field toward the higher numbered beds.

Fertilizers should be tailored to the individual crop to reduce costs and prevent over-application. Nitrogen requirements for common vegetable crops vary from less than 120 lb/acre to greater than 200 lb/acre (Table 2).

Table 2. Nitrogen requirement for vegetable crops based on seasonal nitrogen uptake (Gaskell et. al 2007).

Low <120 lb/acre	Med 120–200 lb/acre	High >200 lb/acre
Baby greens	Carrot	Broccoli
Beans	Corn, sweet	Cabbage
Cucumbers	Garlic	Cauliflower
Radish	Lettuce	Celery
Spinach	Melons	Potato
Squashes	Onion	
	Peppers	
	Tomatoes	

Crop need and estimated nitrogen release from organic matter and the previous season's legume cover crops can be used to determine a proper fertilizer application rate. The required nitrogen can be calculated using Equation 1:

$$\text{N to be applied} = \text{plant N requirement} - [\text{N mineralized from organic matter} + \text{N mineralized from previous legume cover crop} + \text{N from irrigation water}]$$

Accounting for nitrogen release from soil organic matter is difficult. If management practices have

included regular additions of compost, manure, or cover crops, then a medium to high range of nitrogen mineralization can be expected.

A typical range for nitrogen mineralization from organic matter in agricultural soils is 50 to 200 pounds per year. The amount of nitrogen mineralization will be affected by soil organic matter and applications of manure, compost, and leguminous cover crops. Because mineralization is dependent on many different factors, more site-specific mineralization rates can be determined by establishing a “zero N plot” in the field and sampling crop tissue (Sullivan, McQueen, and Horneck 2008).

Most soil-testing labs offer a variety of analyses and soil test data, such as those listed below, which can be used to plan amendment applications:

- Most crops prefer a soil pH of 6.5 to 7, although the acceptable range varies. A few crops prefer acidic conditions. Soil pH can be changed by adding lime, sulfur, and other materials.
- A lime requirement test indicates how much lime is necessary to decrease soil acidity.
- Soil organic matter values are not reliable predictors of nitrogen mineralization. Soil organic matter values can indicate the effectiveness of soil-building practices, such as cover cropping and amendment applications.
- Nitrate values will indicate whether nitrogen fertilizer was applied in the right amount, if samples were taken in early fall. This timing is particularly important in maritime climates, such as those west of the Cascade Mountains in Washington and Oregon. These data can be used to adjust future fertilizer applications. Some year-to-year variation can be expected, due to varying weather.
- Soil nutrient deficiencies can be identified and corrected with amendments.

Conclusion

Healthy soils are living, dynamic systems that provide many functions essential to human health and habitation. Soil sampling and analysis can be used not only to sustain plant and animal productivity but also to maintain or enhance air and water quality. Using data from soil sampling and analyses to tailor farm management decisions can also improve both farm profitability and environmental stewardship.

Acknowledgements

Oxbow, Local Roots, and Full Circle Farms participated in developing and reviewing this fact sheet. Dr. Craig Cogger, WSU Puyallup, and three anonymous reviewers provided additional technical review. Illustrations by Andrew Mack and Doug Collins.

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EM050E