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MontGuide

Soil Sampling Strategies

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Understanding different soil sampling strategies enables more accurate characterization of soil nutrient levels and variability, and therefore cost-effective fertilizer management.

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THE ULTIMATE GOAL OF SOIL SAMPLING IS TO characterize the nutrient status of a field as accurately and inexpensively as possible. Due to differences among fields combined with differences in management, there is no single optimal strategy for collecting soil samples in all production systems.[1] However, having a better understanding of different soil sampling strategies should help you identify strategies that fit your goals. For specific information on soil sampling plans and methods, refer to MSU Extension's Nutrient Management (NM) Module 1 (#4449-1). See "Extension Materials" at the back of this publication for web address and ordering information.

Types of Sampling

Fields can be broken into either zones or grids (Figure 1) when developing a soil sampling plan. Within those zones or grids, soils can either be taken randomly or sampled at or near the intersections. Soil test values from random and grid sampling are often used to provide a single estimate for an entire field. This value may then be used to calculate fertilizer application rates (see Montguide MT200703AG, *Developing Fertilizer Recommendations for Agriculture*, for details).

Random Sampling

Uniform fields can be randomly sampled throughout the entire field. To see long-term trends in soil nutrient data, these points should be georeferenced with a global positioning system (GPS) receiver and sampled in these same locations in subsequent years.

Grid Sampling

Grid sampling can be particularly useful where there is little prior knowledge of within-field variability. It also avoids sampling bias that could result from the collection of an unrepresentative composite sample due to a high portion of subsamples collected from the same region. Two common types of grid sampling include grid-cell and grid-point. Grid-cell soil sampling randomly collects either one or multiple subsamples throughout the cell for a composite sample. Grid-point soil sampling collects one or multiple subsamples around a georeferenced point within a grid or at a grid intersection.

Types of Zone Sampling

Zone sampling is a soil sampling technique that assumes that each field contains different soils with unique soil properties and crop characteristics, and therefore should be separated into unique zones of management (Fleming et al., 2000). For example, regions of fields that have had different crop history, yield or fertilizer treatments, and/or that vary substantially in slope, texture, depth and/or soil color should be separately sampled and therefore established as a zone.

Unlike grid sampling, the number of zones and their shape and size will depend on the degree of field variability. In addition, zone sampling reduces the number of soil samples compared to grid or random sampling and allows for variable rate fertilizer applications ("prescription" rates). Variably applying fertilizer can improve yields, reduce fertilizer costs and increase the potential of receiving Conservation Security Program (CSP) funding from the Natural Resources Conservation Service (NRCS).

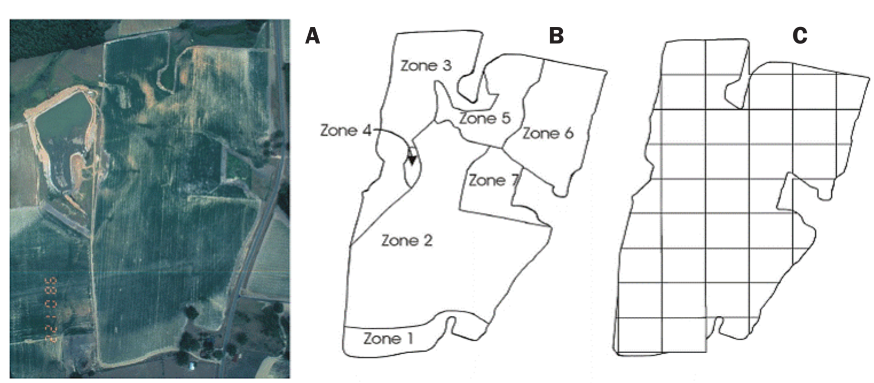

FIGURE 1. (A) Aerial photograph of 67 acre field (B) Management zones and (C) Two acre field grids (Rains and Thomas, 2001).

[1] Because soil nutrient variability is unique per field, statements made in this document should not be considered firm recommendations for every field.

Soil Series

Soil series zone sampling identifies areas within and between fields that are unique from each other by using soil survey and topographic maps. Each soil series differs in its soil properties and will likely have different levels of available nutrients. Therefore, separate soil samples for each soil series in a field are collected. Soil test results may then be area-weighted based on the acreage of each soil series. Unless the soil series maps are available at a 1:8,000 scale or smaller (termed "Order 1" by NRCS), use of digitized soil surveys to delineate zones is discouraged. Most digitized soil maps currently do not map areas that are 2.5 acres or less, making their use for within-field nutrient management less desirable. Soil survey maps may be obtained from your local county NRCS office, Cooperative Extension Service office, Soil and Water Conservation districts or online at: http://websoilsurvey.nrcs.usda.gov/.

Topographic/Geographic Unit Sampling

Fields vary in natural features such as elevation, hilltops, slopes or depressions. Topographic/geographic unit sampling assumes these features differ in soil characteristics and therefore uses these features to establish unique zones. There are basically two different types of topographic/geographic unit sampling: area-based and point-based sampling. Area-based soil sampling means that more than one soil sample is collected and composited from near the center of each topographic zone, whereas point-based soil sampling only collects one sample from the center of each topographic zone (Franzen et al., 1998). For free topographic maps, go online at: www.nris.mt.gov. The best topography maps are generated from real time kinematics (RTK) GPS. Be aware that digitized elevation models (DEM) are derived from sparse elevation sampling and then converted to whatever scale the map legend relates, meaning slight changes in elevation are not necessarily accurate.

Remote Sensing Sampling

Remote sensing is the process of gathering data from a distance. It uses images[2] collected by satellites or aircraft and combines those images with tabular information, digital maps and other digital data. That information is entered into a geographic information system (GIS), which is a computer database that retrieves, stores, analyzes and maps geographical information. The collected data or images, in the form of distinct wavelengths, are then formulated using common indices such as normalized difference vegetation index (NDVI), green normalized difference vegetation index (GNDVI) or reflectance ratio vegetation index (RVI). The indices are mapped, indicating varying levels of a particular parameter such as plant nutrient content, water content, soil parameters (such as color) and yield. Because the relationship between indices and any of the above parameters are only estimates based on other research, calculated values should be ground-truthed and verified.

Yield Sampling

Crop growth and yields vary due to a number of soil parameters, such as texture, drainage, depth and management practices, including land shaping, spreader patterns and previous land use. Yield sampling zones use crop yield maps generated from combine yield monitor data, to determine where to soil sample. Yield data collected from yield monitors can be used in combination with GPS to map yields. Overall, yield maps are best used for zone delineation if the field is broken into arbitrary grids through a GIS program and the yields within each grid are averaged. Grids that have yields above the average are given a value of +1, yield grids below average are given a value of -1, and average yields for a grid are given a value of 0. If this procedure was repeated for each year's yield data, regardless of crop, a normalized yield[3] frequency map would result when the multi-year normalized yield data were combined in a spreadsheet and then mapped. The resulting maps indicate zones that consistently yield high or low and those that do not.

If a consistent factor controls yield variability in a field, then the distribution of this factor, and thus the distribution of crop yield, can assist in determining where to soil sample. For example, if low levels of a nutrient correspond to low yield areas, applying that nutrient should increase yield in those areas. However, if soil test results indicate adequate or high nutrient levels in low yielding areas, then the soil should be examined for compaction and other physical characteristics that could affect yield, particularly those that affect water storage or drainage. Fertilizer can then be reduced in these areas.

TABLE 1. The number of subsamples required to provide a composite soil sample of given levels of accuracy and confidence for nitrogen, phosphorus and potassium (Swenson et al., 1984).

Confidence Level	Accuracy Level[a]					
	± 15%			± 25%		
	N	P	K	N	P	K
Percent	Number of Subsamples					
90	25	34	7	10	12	3
80	18	21	5	6	8	2
70	10	14	3	4	5	2

[a] Percent deviation from the mean

[2] Created from surface light refractance.

[3] Normalized yield is obtained by dividing each sample point by the field average and is expressed as a percentage of the average yield of the field. Spatial yield patterns may then be compared across different crops and years. For example, a normalized yield of 125 percent is actually 25 percent greater than the field average while any area less than a 100 percent normalized yield is not reaching full yield potential.

Management Zones

The management zone approach combines a number of zone sampling techniques to establish unique management zones (Figure 1B). Combinations of prior experience, soil survey maps, yield maps, topography, electrical conductivity (EC; a measure of salinity) from sensors such as the Veris EC sensor or the EM-38 magnetic sensor, soil color, organic matter (O.M.), soil nutrients, moisture and remotely sensed vegetation indices are all useful in establishing multiple layers of information to develop unique zones. These layers of information may be used either by themselves (described above) or in other combinations to establish unique zones. For practical reasons, fields are generally broken up into 3 to 5 management zones in Montana.

Recommendations Based on Research Results

Representative Soil Sampling

Some soil nutrients have more spatial variability within a field than others. For example, phosphorus (P) levels have been observed to vary more than any other nutrient level within a field (Mallarino and Wittry, 2004). The greatest variability is observed in areas with long cropping histories (Mallarino et al., 2006).

For practical reasons, only one soil sampling strategy will generally be used for all tested nutrients; however, if one nutrient consistently limits yield, the method that is most accurate for that nutrient should be used. For example, area-based topographic sampling is better than grid sampling at estimating nitrogen (N) concentrations (Franzen et al., 1998). The grid approach is the best approach for measuring P in heavily fertilized fields, whereas both the grid and management zone approaches are good at measuring potassium (K) levels (Mallarino and Wittry, 2004). In addition, the grid-point method is better at measuring soil test P and K than the grid-cell method (Wollenhaupt et al. 1994). However, the management zone approach is the best approach for measuring O.M. and pH variability (Mallarino and Wittry, 2004). In areas with a history of lower soil P values or use of modest amounts of seed-placed starter fertilizer, a zone approach for all soil nutrients is valuable (Franzen, 2008).

If a similar weight is given to all standard soil parameters, grid and management zone sampling should equally provide the greatest success at determining nutrient variability across all fields (Mallarino and Wittry, 2004). The management zone approach generally results in fewer soil samples than the grid approach, yet may take more planning time. The best strategy is to first determine the degree of variability within a field, and use grid sampling if variability is low (e.g. nutrient range is less than a factor of 2 to 3 across the field), and use zone sampling if variability is high.

Cautions

Furrows, headlands and potholes should all be avoided (Swenson et al. 1984). In addition, concentrating sampling along a straight line may bias soil sampling results if that line parallels previous fertilizer application bands.

If a specific factor is not a consistent predictor of yield, this may bias the sampling process. In addition, any factor that reduces final grain yield may also cause discrepancies between remotely sensed yield and actual yields (Lobell et al., 2005). Remotely sensed images not collected at the optimum time of development could also affect crop yield prediction.[4] To reduce these discrepancies, other layers of information such as topography, soil and crop canopy images, etc. should be incorporated with yield maps in determining sampling zones (Mallarino and Wittry, 2004).

Although grid sampling accounts for more nutrient variability than soil series, elevation zone and management zone sampling (Mallarino and Wittry, 2004), grid sampling requires sampling sites to be close enough to assure important information will not be missed. In addition, even though soil series sampling is generally less accurate and produces lower yields than grid sampling, soil series sampling has resulted in greater profits, primarily due to fewer soil samples and lower fertilizer costs (Clay et al., 2000).

Number of Soil Samples to Collect

The accuracy of, and confidence in, a soil test level is positively related to the number of soil samples collected per field. Accuracy measures how close the soil test value is to the actual field average, whereas confidence is how often the level of accuracy can be repeated (Swenson et al., 1984). For example if a field is sampled 10 times, at an accuracy level of ± 20 percent from the actual field average and a confidence level of 80 percent, 8 of the 10 composited soil samples will have soil test values within ± 20 percent of the field average. Average values from the other 2 composited soil samples will be outside of this range (e.g. 20.1 percent or greater). The number of subsamples required to provide given levels of accuracy and confidence for N, P and K are listed in Table 1 (Swenson et al., 1984).

To maintain a particular level of confidence and accuracy, the number of subsamples increases only slightly as field size increases (Swenson et al., 1984). For example, at a confidence level of 80 percent and accuracy level of ± 15 percent, the optimum number of subsamples increased from 17 to 20 for N as field size increased from 20 to 80 acres (Swenson et al., 1984).

Because it is likely that only one set of subsamples will be collected, the highest number shown for a given confidence level and accuracy level should be collected (Table 1). For example, if an accuracy level of ± 25 percent is deemed sufficient at a 90 percent confidence, then 12 subsamples per field (or zone) should be collected, composited and analyzed for N, P and K. As a cautionary note, a high desired confidence and accuracy level increases the number of collected samples.

[4] The optimum physiological stage to estimate yield potential in small grains is between Feekes growth stage 4 and 6 (Moges et al., 2004).

Conclusion

Because it is not practical to use different sampling strategies for different nutrients within a field, grid sampling and management zone sampling appear to be the best compromises to estimate nutrient levels. Practically speaking, the time required obtaining soil samples and the sampling budget dictate the number of soil samples that should be taken. However, incorporating time, budget and sampling strategy to determine the number of subsamples required for desired levels of accuracy and confidence should allow for the best, most cost-effective determination of available nutrients.

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Extension Materials

Developing Fertilizer Recommendations for Agriculture (MT200703AG). Free. http://msuextension.org/publications/agandnaturalresources/mt200703AG.pdf

Nutrient Management Modules (#4449-1 to 4449-15). Free. http://landresources.montana.edu/nm

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