MANAGEMENT ZONES SOIL SAMPLING: A BETTER ALTERNATIVE TO GRID AND SOIL TYPE SAMPLING? [1]

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Introduction

Global positioning systems (GPS), yield monitors, various forms of remote sensing, new computer software, and variable rate technology are new tools available to producers. Intensive soil sampling and crop scouting methods that directly relate each sample or measurement with their geographical coordinates complement the new technological package. Soil testing is a diagnostic tool that adapts well to site-specific management because it can assess nutrient availability of different areas within a field. Intensive sampling, soil test mapping, and variable-rate application of fertilizers or manure can improve the efficacy of nutrient management compared with the conventional practice of applying a uniform rate across a field. However, the spatial variation of nutrients within fields makes soil sampling one of the most important sources of error in soil testing, and may also be a limiting factor for optimal use of these new technologies. Traditional soil sampling recommendations are changing to adapt to the new precision agriculture technologies. This presentation discusses soil sampling methodology and summarizes results of Iowa research conducted in assorted producers' fields. This research complements other research (not discussed here) studying the effectiveness of variable-rate fertilization.

Conventional Soil Sampling and Grid Sampling

The amount and pattern of nutrient variability vary greatly between fields and are affected by soil type, topography, fertilization history, and many other factors. Traditional soil sampling recommendations developed mainly during the 1960s and 1970s suggest separating sampling areas on the basis of differences in previous management, soil map units, and (sometimes) topography. These three factors are known to influence the supply of many nutrients. Soil chemical and physical properties influence nutrient availability directly by affecting the total amount of a nutrient in the soil, its availability for plant growth, and possible losses due to movement of nutrients or soil. In addition, soil type can affect nutrient availability indirectly by affecting yield potential and nutrient removal. Crop and soil management practices, such as crop, tillage, nutrient removal in harvested products, and the rate and application method of fertilizers or manure also have a marked influence on nutrient supply and on availability changes over time. Most recommendations suggest collecting at least one composite soil sample made up of about 15 cores from each sampling area. Some recommend a certain number of samples and/or cores per unit area. This approach seemed to work well until the late 80s, when dealers and producers began to adopt precision agriculture technologies.

These technologies (mainly GPS) allowed for recording soil-test values and geographical coordinates of sampling points, and for processing other field information into layers that could

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be easily visualized in maps. This new development lead to a full appreciation of the high nutrient and yield variability occurring in most fields. It became obvious that presumably uniform map units of commonly used soil survey maps actually had very high nutrient variability, especially P, K, and pH. Moreover, in many fields with long histories of fertilization variability patterns did not follow patterns of soil map units. Thus, intensive grid sampling methods that effectively ignore landscape or soil mapping units began to be adopted rapidly in the early 1990s.

There are many variations of the grid soil sampling method. Grid sampling subdivides a field into a systematic arrangement of small areas or cells, and one composite sample usually made up of 6 to 12 cores is collected from each cell. Early users collected cores following either a random or a systematic pattern from the entire area of each cell, a method often referred to as grid-cell sampling. More recently, users of grid sampling methods collect the cores from smaller areas (500 to 1500 sq. ft.) located near the center of each cell or at the intersection of grid lines, a method often referred to as grid-point sampling. Soil-test values collected by grid-point sampling may be directly mapped to represent each cell area or may be used to create interpolated maps using one of several methods available in common computer software. It quickly became apparent that cell sizes of about 4 acres failed to describe the high variability occurring in the fields (mainly of available P, K, and pH), and currently a cell size of about 2.5 acres is used. As a consequence, 20 to 30 samples are collected from typical Iowa fields where seldom more than five or six samples were collected before.

Sampling by Soil Map Unit or Grid Sampling?

A large project has compared various grid sampling strategies and sampling by soil map unit for P, K, pH, and organic matter in several Iowa fields. The procedures included grid-cell sampling of various cell sizes ranging from 0.15 to 4 acres, grid-point sampling with distances between points ranging from 80 to 400 feet, and sampling by soil map unit. Results of this project have been shown in previous conferences (Mallarino and Wittry, 1998, 2000). The results for P, K, and pH showed that markedly different answers and fertilization or liming rates result from using different sampling schemes. The nutrient variability and its patterns changed markedly across fields and nutrients. No single sampling scheme would be the most cost-effective across all fields and nutrients. A large number of samples will describe nutrient availability over a field more accurately than a few samples, but the costs will also be higher. Although the commonly used grid-point sampling method based on 2.5-acre cells described nutrient variability better than a traditional sampling by soil map unit method when adequate numbers of cores per sample were collected, it resulted in three to 10 times the number of samples. To be economically effective, any new sampling method that increases costs should result in either lower fertilization rates or increased crop yield response to fertilization. Although it is difficult to assign an economic value to the impact of improved management on environmental conservation, the effectiveness of a new soil sampling or fertilization practice in maintaining or improving water quality should also be considered.

Previous presentations in this conference (Mallarino and Wittry, 2000) shared results of research in many Iowa producers' fields showing small and infrequent corn and soybean yield differences between uniform-rate or variable-rate fertilization methods. This was the case even though grid cell sizes of 0.2 to 0.75 acres and 12 cores per sample were used, and low-testing areas of variable size existed in most fields. The results did show, however, that variable-rate fertilization reduces large-scale soil-test variability, reduces fertilizer application to high-testing areas, and allows for better maintenance of P and K because yield-monitor maps provide good estimates of yield potential for different areas of a field. There is little doubt that fertilizer or manure application using variable-rate technology can potentially reduce delivery of P and other nutrients to surface water resources (Mallarino et al., 2001). However, small and infrequent yield advantages for the intensive soil sampling - variable-rate fertilization package clearly show that soil testing costs have to remain low so the technology becomes economically effective. Ongoing studies in Iowa were designed to answer these questions by evaluating a new management zone soil sampling method.

Management Zones Soil Sampling

Management zone sampling is an attempt to improve the traditional sampling by soil map unit method by using information that can be collected using precision agriculture technologies. Zone sampling can reduce the number of samples and sampling costs while maintaining acceptable information about nutrient variability within a field. This approach is compatible with the fact that soils are sampled not only for P and K but also for other nutrients and for purposes other than fertilization. Sampling by zone assumes that sampling units can be identified on the basis of areas with different soil or crop characteristics across a field and that patterns are likely to remain temporally stable. Specific criteria used to delineate management zones, other than soil survey maps, vary depending on tools available to producers, their costs, and on how they adapt to the particular conditions of the region or field. This has been shown by previous work in Missouri (by Newell Kitchen and collaborators), North Dakota (by David Franzen and collaborators), South Dakota (by David Clay and collaborators), and by our own research.

Yield maps can be used to define different soil productivity areas within a field and is a useful criterion to delineate management because different yield levels likely have different nutrient requirements, influence nutrient removal and nutrient trends over time, and may influence economically optimal fertilization rates. However, stable within-field yield patterns over time are observed in some fields but not in others. Yield maps from many years are needed and this may, or may not, result in an effective criterion to establish management zones relevant for nutrient soil sampling. Topography (which includes elevation and slope) and aerial images of both bare soil and crop canopy can be used to identify management zones because they tend to reflect different soil properties and may inexpensive. Soil electrical conductivity (EC) can be estimated by on-the-go electromagnetic induction methods using EM or Veris systems (Fenton, 2000). It is useful to describe the spatial variation of topsoil depth and other physical and chemical soil properties, and often EC maps are correlated with crop yield over a field. Previous research and our own work have shown that these layers of information almost always are useful to adjust soil survey maps. Many producers and nutrient management planners often do not consider that soil survey maps were prepared at a certain scale, and were not designed to identify small areas with different soil properties. Important aspects to consider are that independently of the information used to delineate zones, several cores per composite sample (at least 12 to 15 cores or more for large zones) are needed and the method is not designed to assess the small-scale nutrient variability.

We compared various soil sampling methods in eight intensively sampled Iowa fields. The maps in Fig. 1 show, as an example, soil-test P values for three fields sampled using a management zone method that considered the information layers mentioned above and other sampling methods. The differences between sampling methods varied greatly on the nutrient studied and the field. In some fields most methods coincided in identifying areas of the field with contrasting soil test values. In most fields (as expected), grid sampling methods uncovered more nutrient variability than methods based on soil map units, elevation, or management zones but the number of samples (and soil testing costs) was higher.

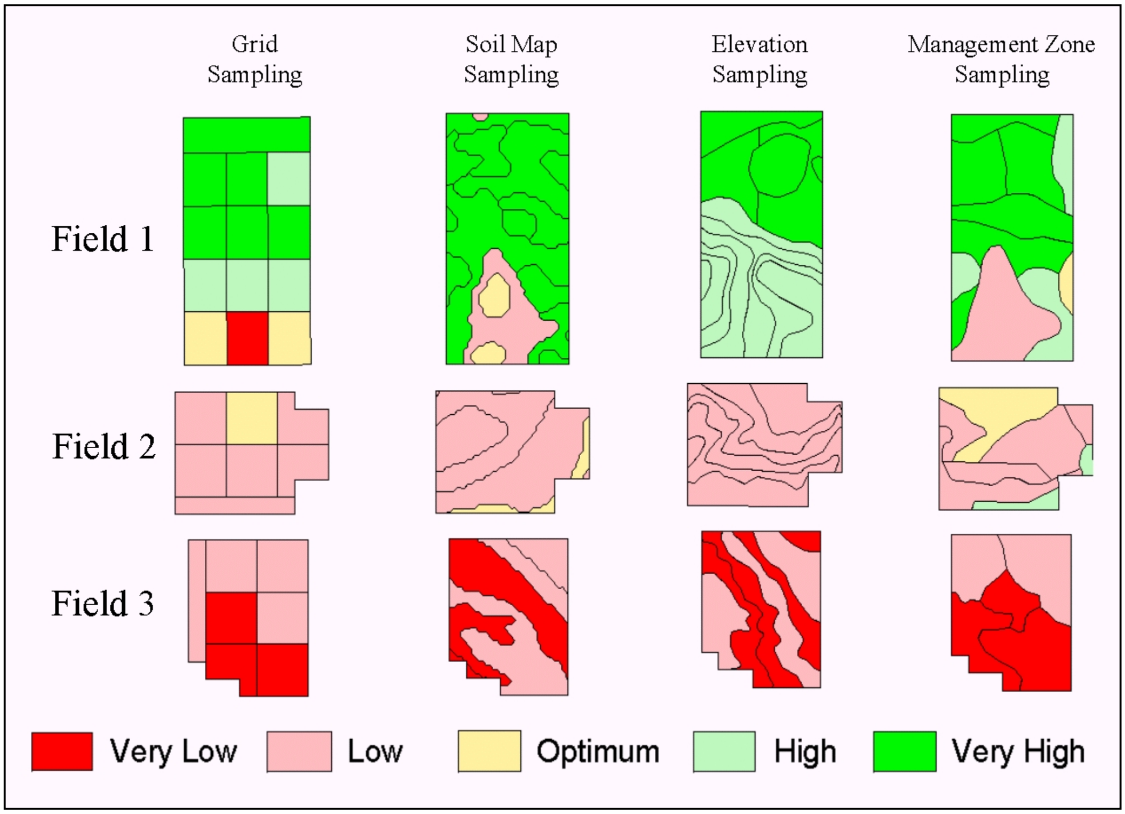

Fig. 1. Effect of the soil sampling method on estimates of soil-test P for three Iowa field portions measuring 30 to 50 acres in size.

An important aspect to consider when comparing methods for identifying sampling units is how effective the methods are in reducing the nutrient variability within each sampling unit. Methods that minimize the within-unit variability and maximize the between-units variability are the most effective for a certain number of samples. The data in Table 1 summarizes the efficacy of each sampling scheme in reducing the within-unit variability. Few generalizations can be made across nutrients and fields, and the results confirm that soil-test variability tends to be field specific and nutrient specific. In these fields, all sampling schemes performed comparatively better in reducing within-unit variability of pH and organic matter than of P or K. Long histories of fertilization substantially increase small-scale variability of soil-test P and K and tend to mask natural variation. The ranking of the schemes varied considerably among the soil tests. The management zone and grid sampling schemes were more effective for P, K, and pH across all fields than other schemes. Because no sampling scheme should be expected to be best across all conditions, informed decisions about the most effective sampling scheme can be made only after an intensive (and expensive) sampling method has shown the amount and patterns of the variability for the different nutrients. Otherwise, knowledge of the field history (mainly the history of fertilizer and manure applications) could provide useful clues concerning likely nutrient levels and corresponding crop response to assess the potential return to expensive sampling schemes.

Table 1. Percentage of fields in which each of four soil sampling methods significantly reduced within sampling-unit soil-test variability compared with variability across sampling units.

Soil test	Soil map units	Grid sampling	Elevation	Manag. zones
	%			
P	38	50	38	38
K	50	63	50	63
pH	62	88	50	100
Org. Matter	100	75	88	88

General Recommendations

Specific recommendations that apply to all fields and conditions are not possible because the effectiveness of different sampling schemes and layers of information vary greatly across regions and fields, and with the sampling objectives and economic considerations. Intensive grid sampling schemes are more effective in describing small-scale variability than other methods but are more expensive (especially in large fields) due to higher sampling and analysis costs. On the other hand, the effectiveness of the traditional sampling by soil map unit can be improved by using other layers of information. A management zone scheme will represent small-scale soil test variability less accurately than an intensive grid sampling scheme because the number of samples will be lower. However, there will be obvious soil testing cost savings, and on-farm research has suggested that it is not possible to measure small-scale nutrient variability cost-effectively with current grid sampling methods and probably cannot be managed appropriately with current variable-rate technology. A management zone sampling scheme will be especially effective when soil type and nutrient removal by crops are major factors in determining nutrient variability across large areas. The management zone concept is flexible to accommodate different information layers, sampling objectives, and economic conditions.

Obviously a compromise is needed between soil sampling precision and economic feasibility. Producers and nutrient management planners must consider that efforts should be dedicated to apply fertilizer more uniformly, that investing in expensive sampling schemes on predominantly high-testing fields will not be cost-effective, and that the benefits of expensive soil sampling schemes widely spaced over time may not compare favorably with more frequent (every other year, for example) and less expensive sampling schemes. Intensive and spaced sampling schemes may not provide useful soil test trends that frequent and cost-effective sampling methods may provide. Available research suggests no clear cut recommendation is possible concerning grid sampling or management zone sampling methods. Either method could be effective depending on the producer management philosophy and particular conditions of each field.

Acknowledgments

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References Cited

Fenton, T.E. 2000. Electromagnetic induction technology and precision agriculture in Iowa. p. 161-168. *In* The Integrated Crop Management Conf. Proceedings. Nov. 29-30. Iowa State Univ. Extension. Ames.

Mallarino, A.P., and D. Wittry. 2000. How can we make intensive soil sampling and variable-rate P and K fertilization cost-effective? p. 203-210. *In* The Integrated Crop Management Conf. Proceedings. Nov. 29-30. Iowa State Univ. Extension. Ames.

Mallarino, A.P., and D. Wittry. 1998. Soil sampling strategies for variable rate P and K fertilization and liming. p. 251-256. *In* The Integrated Crop Management Conf. Proceedings. Nov. 17-18. Iowa State Univ. Extension. Ames.

Mallarino, A.P., D. Wittry, and J. Klatt. 2001. Using the Iowa phosphorus index and variable-rate technology for effective agronomic and environmental phosphorus management. The Integrated Crop Management Conf. Proceedings. Dec. 5-6. [In this publication] Iowa State Univ. Extension. Ames.