IMPACT OF GRID POINT SAMPLING INTENSITY ON PHOSPHORUS AND POTASSIUM UNCERTAINTY

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ABSTRACT

Soil testing is the foundation for the determination of nutrients for crop recommendations. The reliability of which is based the collection of a representative field sample, appropriate test method, accurate laboratory analysis, and the nutrient recommendations. The success of the soil testing process is fundamentally dependent on the collection of a representative soil sample. For whole fields this entails a composite of multiple soil cores denoting the collection area, whereas for grid sampling cores are combined around the grid point.

Considerable research has been conducted across the Great Plains to address soil sampling techniques used to assess nutrient status. For whole field composite soil samples only the mean is measured with no estimate of the variance. Cameron et al., 1971 reported that 20 cores provided a mean estimate within 10% for phosphorus 70% time, but were inadequate on highly variable fields. Swenson et el., 1984 reported that 20 cores provided a mean estimate within 15% for nitrate 80% of the time. Work by Franzen and Peck 1993, has shown substantial spatial variability, and suggested sampling intensities of one sample per acre would be required to characterize nutrient variation in most fields in Illinois. Often high variability of immobile nutrients (P and K) of composite samples is associated with the fertilizer bands from previous nutrient applications. Fields that have high soil test values tend to have higher spatial variability (Mallarino, 1996 and Clodfelter, et. al., 2005). Increasingly fields are grid sampled in the region based on 2.5 acre grid approach, compositng 3-12 cores per grid point, however little information has been published on grid point nutrient variation.

Further complicating soil sampling are impacts of soil tillage systems and application of livestock manures. With no-till and reduced tillage systems nutrients increasingly stratify near the surface, requiring accurate sample depth control (Wolkowski, 2002). If the sample is collected at a shallower depth, soil test results will over estimate the nutrient concentration of the sample. With regard to livestock manures, surface applications are often nonuniform resulting in high spatial variability.

The primary objective of this project were to estimate grid point sampling uncertainty for pH, P and K on fields on the Great Plains and Midwest.

MATERIALS AND METHODS

Grid point soil samples were collected at fifteen field sites across seven states in the fall of 2006 and 2007. Tillage practices ranged from no-till to conventional till and included sites where manured had been previously applied. Twelve individual soil cores, were taken in a structured pattern ranging from 2 to 8 feet from the center of a geo-referenced grid point. Sampling depths ranging from 0-6", 0-7" or 0-8” for dependent on location. At two locations soils were sampled to an additional depth of 6 - 12". At one location 24 individual cores were sampled from 2 to 8 feet from the center geo-referenced grid point.

Grid point soil cores were dried, pulverized, thoroughly mixed and analyzed for pH, SMP buffer pH, Bray P1 phosphorus, ammonium acetate K, and DTPA extractable zinc, in triplicate. Laboratory quality control procedures included standard reference soils from the Agricultural Laboratory Proficiency (ALP) Program, blanks and duplicates.

RESULTS

Spatial variability grid point of phosphorus (P), based on 12 core composites, indicated RSD values generally were between 12.2 - 24.8%, with the exception of five no-till sites (Table 1) which ranged 19.2 - 60.5%. The no-till sites were characterized by low to medium P concentrations (11 - 40 mg kg^{-1} P) and had received past band applications of P fertilizer materials. Results for K indicate RSD values ranged from 6.4% - 30%, with ten of twelve fields averaging 12% for soils ranging from 124 to 458 mg kg^{-1} K. Two fields with highest variability had received past band applications of K fertilizer. For soils ranging from pH 5.8 to 7.7 RSD values ranged from 3.0% to 9.0%. Across sites, no-till fields tended to have the highest spatial variability grid point pH.

Individual core results indicate that composite mean P concentration decreased going from 3 to 12 cores and overall improved precision. For site #15 the RSD value for three core composite was 43.6%, while that for 6 cores was 40.9% and eight cores fell to 35.1%, resulting in an uncertainty of ± 4.1 mg kg^{-1} P (Table 2). For site #43 a reduced tillage field the RSD value for three core composite was 38.1%, while that for 6 cores was 24% and eight cores fell to 21%, resulting in an uncertainty of ± 6.2 mg kg^{-1} P. Generally no-till sites were characterized as having skewed populations (skewness > 1.2) with 1 or 2 core subsamples high in Bray P1 concentration. Potassium results indicate composite mean concentrations and RSD values change only slightly going from 6 to 12 cores. For site #57 a no-till site with a mean K concentration of 490 mg kg^{-1}, the potassium RSD value for 3 core composite was 12.5%, while that for 6 cores was 14.0% and twelve cores 12.0%. No-Till sites tended to have the highest RSD values for K of all locations with or without prior application of K fertilizers. Lastly pH grid point variation, for soils ranging from pH 5.8 to 6.7, RSD values for 6 cores ranged 2.9% - 14.2% and for 12 cores ranged from 3.0% to 9.0%.

Individual core results for Bray P1 were further evaluated to assess sampling intensity. Bray P1 mean and RSD values were evaluated for 2 of 12, 4 of 12, 6 of 12, 8 of 12 and 11 of 12 core composites, based on all possible combinations. Results for field #15 (as shown in Table 3), indicate that sampling only 2 of 12 cores, consisting of all 66 possible combinations, resulted in a composite mean Bray P ranging from 13.2 - 25.3 mg kg^{-1} P and RSD values ranging from 0% - 57%. Increasing to 6 of 12 cores resulted in composite mean Bray P ranging from 14.2 - 19.7 mg kg^{-1} P and RSD values ranging from 4% - 36%. Soil core combinations (Figure 1) indicate a rapid convergence of composite mean soil Bray P1 values as the number of cores included increases from 6 to 12 cores for the field #15. Also worth noting is the skewness of the mean data associated with two cores of high Bray P1concentration. . Overall, a minimum of eight core composites were required to obtain a range of mean core combinations within ± 2.0 mg kg^{-1} P of that found for the twelve core composite. Similar results were found for Field #41 (Figure #2).

The number of grid point soil samples composited determines the accuracy and precision of the final result. Accuracy refers to the correctness to the true value, whereas precision is a measure of the reproducibility of the sample result for a given level of statistical confidence. Results of the grid point Bray P1 data were applied to the formula for calculating sample size:

$$n = (t^2 * s^2) / E^2$$

Where t is the student t-values which equal's 1.27, 1.645, 1.96 for the 80%, 90% and 95% level of confidence respectively, E is the accuracy as percent allowable error and s is the population standard deviation. Bray P1 for grid point samples collected from a conventional tilled site (Field #31) with a mean of 45.1 standard deviation of 6.8 mg kg^{-1} P indicate a composite of seven cores would be required to obtain an accuracy of ± 10.0 % of the mean Bray P1 at 90 percent precision level (see Figure 3). Thus there would be only one chance in ten that a composite of seven cores would result in a value exceeding the mean by more than ± 10%.

In contrast for a no-till location such as Field #15 with a mean of 16.6 and standard deviation of 4.8 mg kg^{-1} P a composite of 26 cores would be required to obtain an accuracy of ± 10.0 % of the mean Bray P1 at a 90 percent precision level (see Figure 4). Reducing the precision level to 80%, would still require a composite of 16 cores to obtain an accuracy of ± 10.0 % of the mean Bray P1. Reducing accuracy to ± 20.0 % would still require 6 cores at a 90 percent precision level, however a level this low would be of little value for reliable fertilizer recommendations. Increasing the number of cores composited to12 cores using 90 percent precision level would provide an accuracy of ± 14.0 %.

These results indicate that for Bray P1 soil sampling a grid point of manure and conventional tilled fields with RSD values of 12% - 16%, generally 6 - 8 cores will result in an accuracy of ± 8.0% - 11.0 % based on 90 percent precision level. For no-tilled fields and low testing fields with high variability (RSD 30%), 3 to 4 times more soil cores will be required to obtain an accuracy of ± 10.0 % of the mean Bray P1.

SUMMARY

Results for 12 composited cores, indicates substantial improvement in grid point accuracy and precision going from 2 to 12 cores for phosphorus and to a lesser extent for potassium and pH. Although optimum precision was obtained with 12 core composites per grid point, generally for manure, conventional and reduced tillage sites, 6 - 8 cores resulted in and Bray P1 RSD values of 11% - 19%. For no-till sites RSD values ranged from 17% to 60.5%. Increasing the number of cores composited for low testing and no-till fields substantially improved grid point precision for P, especially with fields where P fertilizers had been band applied previously. An estimate of accuracy indicate 24 - 30 cores are required to obtain an accuracy of ± 10.0 % on these fields.

The results of this research suggest that grid point sampling intensity be assessed for each field based on the nutrient test of primary interest, soil test levels, and field tillage management. For no-till and low testing soils consideration should be given to increasing the number of soil cores composited thereby improving the accuracy of the mean estimate, and providing more accurate nutrient recommendations. Lastly it is strongly suggested that grid point accuracy and precision estimates be periodically collected to assess grid point uncertainty and incorporated in the generation of nutrient maps.

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Table 1. Phosphorus Bray P1 content of grid point samples, five locations fall 2006 and 2007.

	Field #22	Field #31	Field #06	Field #15	Field #35
	Conv Till	Manured	Rd.-Till	No-Till	No-Till
Range (mg kg^{-1})	35 - 63	35 - 60	23 -52	12 - 30	16.3 - 59.0
Mean (mg kg^{-1})	51.7	45.1	41.9	16.6	29.8
Std Dev. (mg kg^{-1})	8.6	6.8	7.6	4.8	11.8
RSD %	16.6	15.0	18.8	29.4	39.8
Uncertainty - CI 95% (mg kg^{-1})	± 5.1	± 3.8	± 4.6	± 2.9	± 6.7

Table 2. Phosphorus Bray P1 grid point core variation, site Field #15 fall 2006.

Number of Cores	Mean mg kg^{-1}	Stdev mg kg^{-1}	RSD %	Uncertainty (95%) ± mg kg^{-1}
3	20.0	8.7	43.6	9.9
6	16.5	6.7	40.9	5.4
8	16.8	5.9	35.1	4.1
12	16.6	4.8	29.0	2.8

Table 3. Core combination Bray P1 statistics, site Field #15 fall 2006.

Number of Cores	2 of 12	4 of 12	6 of 12	8 of 12	11 of 12	12 of 12
Combinations	66	495	924	495	12	1
Max Mean (mg kg^{-1})	13.2	13.6	14.3	14.7	15.0	16.6
Min Mean (mg kg^{-1})	25.2	22.2	19.7	18.7	17.4	
RSD (%) Range	0 - 57	3 - 51	4 - 36	8 - 33	19 - 30	29.4

Figure 1. Range of mean core Bray P1, core combination for soil, site Field #15 fall 2006.

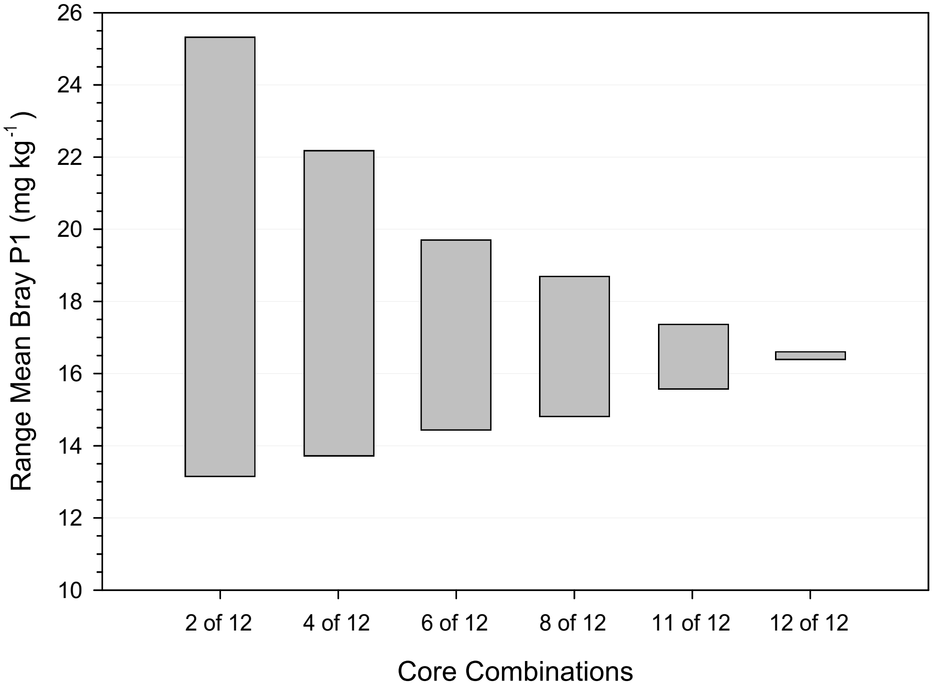

Figure 2. Range of mean core Bray P1, core combination for soil, site Field #41 fall 2006.

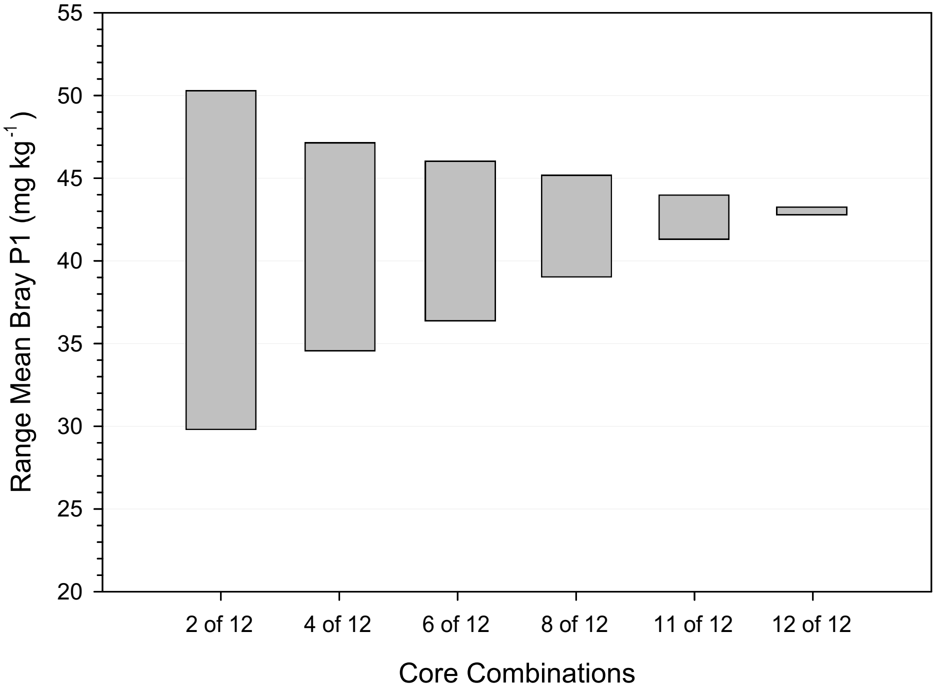

Figure 3. The number of subsamples required for grid point composite cores for soil Bray P1 at various levels of accuracy and three levels of precision, based on sampling RSD of 15%.

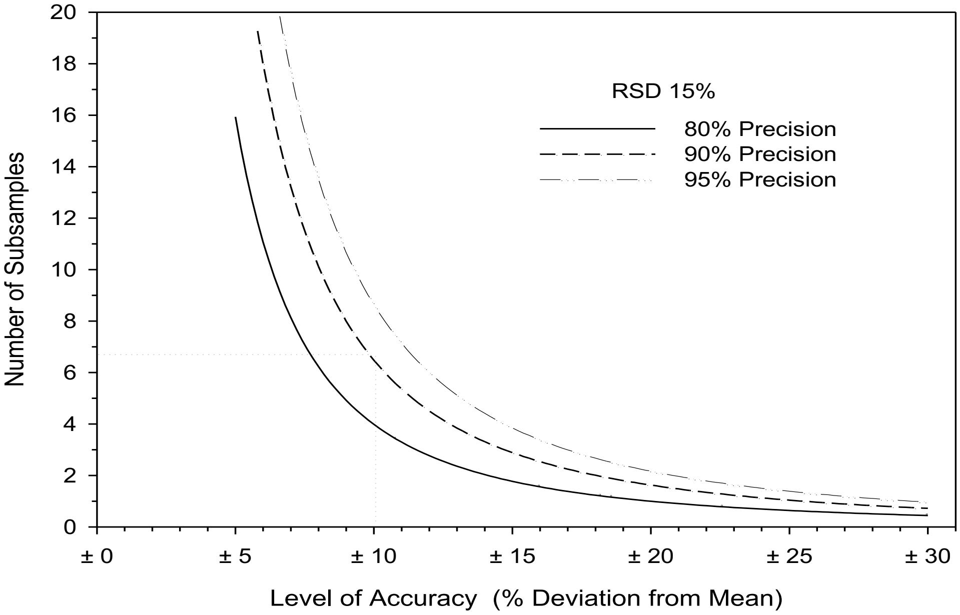

Figure 4. The number of subsamples required for grid point composite cores for soil Bray P1 at various levels of accuracy and three levels of precision, based on sampling RSD of 29%.