OPTIMUM GRID SIZE FOR SAMPLING SOIL VARIABILITY-SCIENCE, MYSTERY, OR MAGIC

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Abstract

The debate over grid sample size and the magic 2.5-acre grid remains to subject for debate. This exercise, looks at taking the results from 100-ft grids (0.23 acre) and compositing cells to create larger units based on 4, 9, 16, 25, or 100 cells averaged to create 200-ft, 300-ft, 400-ft, 500-ft, and 1000-ft grids. The exercise used both soil test phosphorus and soil test potassium and the recommendations based on extracted levels. Soil test P levels in the test field ranged from very low (VL) to very high (H+). Soil test K ranged from low (L) to high (H) in the same area. Increasing the grid size generally resulted in less fertilizer application. With respect to soil test P, the 100-ft grid resulted in an application that was 43% higher than with a 300-ft grid. In comparing a few individual units from the exercise, averaging or compositing resulted in far more errors compared to the smaller sample size. One should recognize that the more samples from an area, the better illustration of soil spatial variability. However, the cost of sampling can be quite expensive and is usually the determining factor in the selection of the 2.5-acre grid.

Introduction

The methods for obtaining meaningful and representative soil samples for use in determining soil nutrient levels and other soil characteristics, have been debated and have changed as the technology for sampling has changed. Soil survey reports have been replaced with digital databases and web-based information. For years, soil tests results were based on samples that were collected from some uniform depth (usually 0-6 inches), composited, mixed, dried, ground, and a portion used for specific soil tests that included pH, extractable phosphorus (P), extractable (K), exchangeable cations (K, Ca, Mg, and Na), exchangeable acidity, cation exchange capacity, organic matter, sulfur, zinc, and other potential "nutrients". The old adage that the results are only as good as the sample was never truer than with soil testing where a small sample could be used to determine lime and nutrient needs for large areas. As technology has advanced, methods available for sampling has also advanced but the soil test is still only as good as the sample collected.

Early soil sample collection was more random than today and not geo-referenced so that the sampler could return to the same spot. At the same time, the soil survey report, prepared by soil classification specialist relying on their skills, was the best source for examining spatial variability based on topography, elevation, drainage, color, vegetation, landscape or other input and often subjective groupings. When area change hands or changed producer, little graphic information could be provided to the new occupant. The best way to learn specific characteristics of land was to meticulously map and analyze positional variation. Early land formation in the Mid-South was achieved by laying out grids, determining elevation, calculating "cuts and fills" and doing the actual movement followed by a subsequent check of the calculations and the results. With today's technology, satellites and other instrumentation can be used to replace tapes, flags, and people for establishing some type of grid network.

With the more modern technologies available, including GPS, soil sampling can be driven by pre-defined management zones, or a strict grid-based pattern. However, when asked about the grid size for sampling, the most common size is 2.5 acres, yet no one can explain the scientific basis for the 2.5-acre grid. The typical answer is economic rather than scientific and lacks the sound reasoning behind scientific inquiry. Common deduction would indicate that the more samples in a general area the better representation of the actual distribution of any given factor. Thus, the more non-uniform an area, the more samples needed to describe the spatial variability. The objectives of this study were to 1) Examine the effects of grid size for soil sampling to determine fertilizer P and K requirements; 2) evaluate variations within cells and the influence of cell means and fertilizer use; and 3) compare techniques to GPS technology and variable rate applications of fertilizer. The exercise was based on 100-ft grid sampling at the Tribbett Satellite Farm prior to actual research on the farm.

Methods

A MSU satellite farm was established for research at Mississippi State University and the Delta Research and Extension Center near Stoneville, MS. Prior to the use of the farm, a 100-ft grid was established by tape and flags for the entire farm area. Some areas could not be sampled due to adverse conditions including water standing. The main field was approximately 85 acres and contained three major soil types. The soil types included Dowling soils (16.7 acres, 19.7%) Dundee silty clay loam (43.0 acres, 50.6%) and Forestdale silty clay loam (25.2 acres, 25.2%). A 200 cell area was selected (10 x 20 cells each at 100 ft x 100 ft). The map was shifted by 50 ft so that the flag became the center of a cell rather than on the corner. This 100' x100' became the basis for a cell and contained 0.23 acres. Each cell of the area (200 total) was sampled around the center flag with multiple cores taken to a depth of 12 inches and divided into 6-in increments for analyses. The samples were dried, ground, and mixed and then submitted to the Soil testing and Plant Analysis Laboratory and Mississippi State University. Soil test results were then assigned to each cell (0.23 acre). To examine the effect of grid size, individual cells were aligned such that a 200' x 200' grid was composed of four cells, a 300' x 300' grid was composed of nine cells and so forth. The area did consist of partial units as the grids were enlarged. The cell size breakdown has been shown in Table 1. As cells were composited into larger units, the value assigned to the unit was the average of the values from each individual cell within the larger unit. Therefore, the mean value for a sample unit represents more than the area sampled had the unit consisted of a 200 ft x 200 ft individual cell. The same was true for each progressively larger unit. Thus, a 200 ft x 200 ft unit had a mean value averaged across four smaller cells. The 300 ft x 300 ft unit was had mean value averaged across nine smaller cells and so forth. This means that the 22.96-acre unit had a value determined from the average of 100 smaller cells. Once the cell (unit) values were determined and mapped, both phosphorus and potassium fertilizer needs were calculated based on the soil test value for the cell, all cells totaled, and the amount of fertilizer calculated for the entire 45.92 acre block.

Table 1: Grid size description for varying grid size at Tribbett Satellite Farm. DREC. Mississippi State University

CELL SIZE (ft)	CELL SIZE (sq ft)	TOTAL CELLS	CELL AREA (Acres)	TOTAL AREA (Acres)
100	10,000	200	0.23	45.92
200	40,000	50	0.92	45.92
300	90,000	22.22	2.07	45.92
400	160,000	12.5	3.67	45.92
500	250,000	8	5.74	45.92
1000	1,000,000	2	22.96	45.92

Results and Discussion

Phosphorus

Soil phosphorus was determined for each of 200 cells assigned in the 45.92 acre block. The graphic representation is shown in Figure 1. A summary of the fertilizer phosphorus needs based on individual cells (100' x 100') has been provided in Table 2. For the very low testing level (VL) 120 lb P_2O_5 has been recommended, 80 lb P_2O_5 for the low (L) testing areas, and 40 lb P_2O_5 for the medium (M) testing areas. The total number of cells needing a certain rate of P as well as the total acres and total fertilizer for the area are shown in Table 2. All 200 cells were accounted for and the total lb P_2O_5 was 2525 lb/acre.

Table 2: Summary of phosphorus needs based on 100-ft grid samplings (0.23 acre) for Tribbett Satellite Farm, DREC, Mississippi State University

LEVEL	RATE	CELLS	AREA	FERTILIZER
	(P_2O_5/Acre)		(Acres)	(lb P_2O_5)
VL	120	37	8.49	1019
L	80	54	12.40	992
M	40	56	12.86	514
H	0	45	10.33	0
H+	0	8	1.84	0
TOTAL		200	45.92	2525

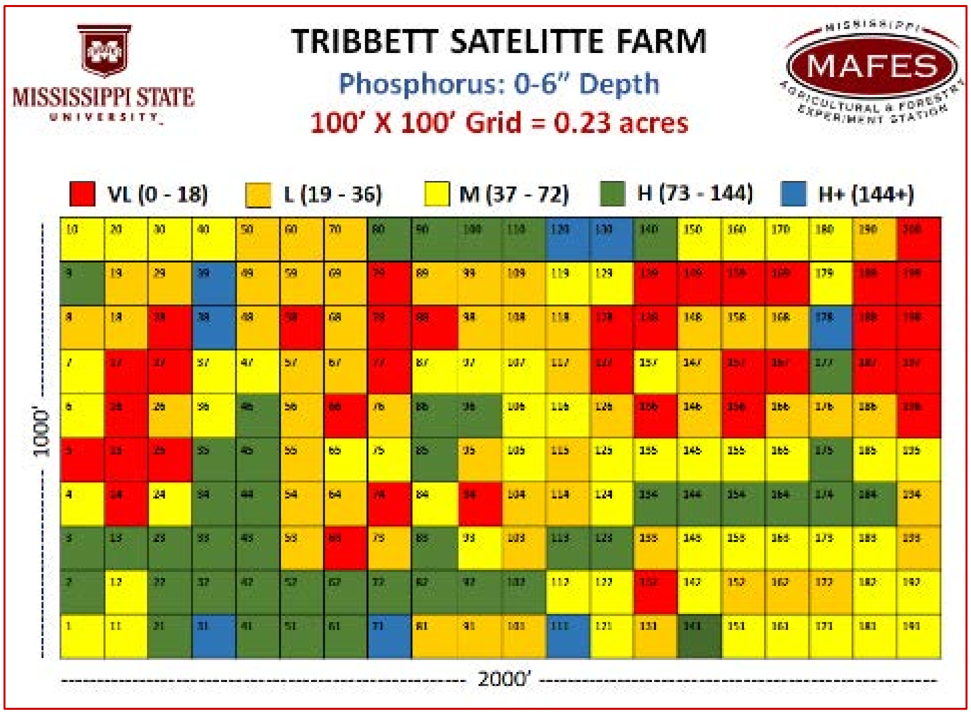

Figure 1. Distribution of soil test phosphorus as determine by Soil Testing and Plant Analysis Laboratory Tribbett Satellite Farm – 0.23 acre grid sampling (100' x 100')

The next step in the process was to combine four cells to create a 200 ft x 200 ft unit with an average soil test value based on the four cells that comprise the larger unit. The 200 cells are reduced to 50 larger units and so far as the grid size was increased. After the manipulation of data was completed, a summary of results is shown in Table 3. As the grid size increased the total amount of fertilizer P decreased. For this study, the least P fertilizer was added based on a 3.67-acre grid sample, keeping in mind that the values of each individual unit is based on the average of 16 cells. The greatest fertilizer P would have been used with the smallest grid size (0.23 acres) and that was 143% of the lowest application rate.

Table 3: Summary of phosphorus fertilizer needs based on grid sample size for 45.92 acre block
On the Tribbett Satellite Farm, DREC, Mississippi State University

GRID	CELLS	P	P_2O_5	0-46-0
(ft)	(acres)	(lb/block)	(lb/block)	(lb/block) (%)
100	0.23	1103	2525	5490 (143)
200	0.92	850	1947	4232 (110)
300	2.07	830	1900	4132 (108)
400	3.67	770	1763	3833 (100)
500	5.74	802	1837	3992 (104)
1000	22.96	802	1837	3992 (104)
AVERAGE		860	1968	4278

Potassium
A similar exercise was completed for soil test potassium and fertilizer potassium application needs. The results for the 100-ft grid at illustrated in Figure 2. Data a graphically presented for each cell based on soil test levels. With potassium, there were no cells in the very low (VL) range and only three cells in the H+ range.

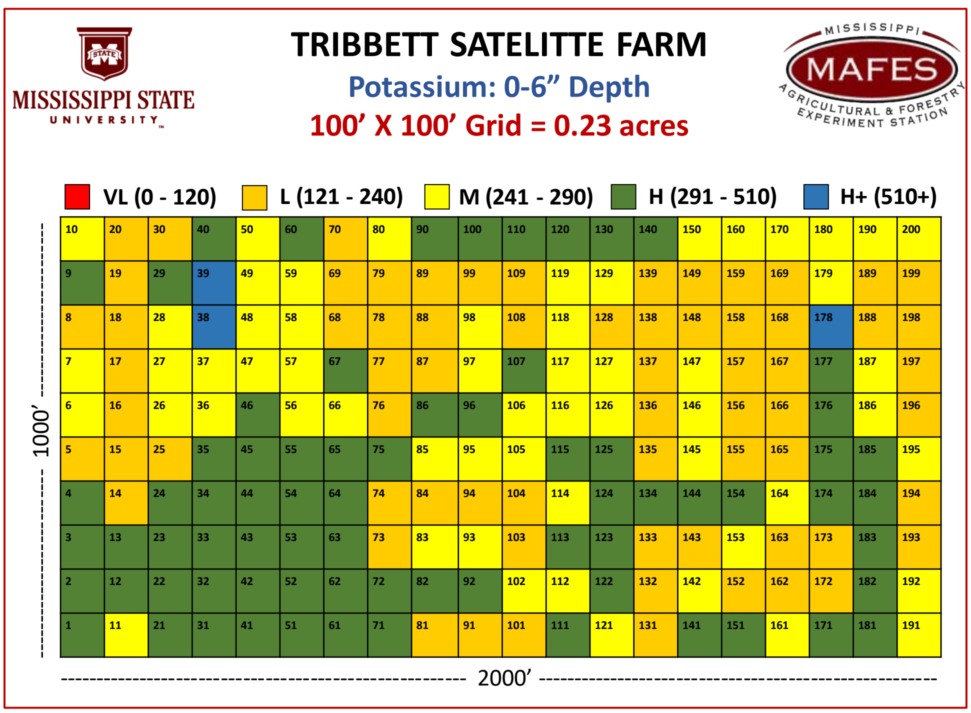

Figure 2. Distribution of soil test potassium as determine by Soil Testing and Plant Analysis Laboratory
Tribbett Satellite Farm – 0.23 acre grid sampling (100' x 100')

The potassium summary is presented in Table 4. The majority of cells feel into the low (L), medium (M) and high (H) range. From Mississippi State University recommendations, even H test potassium areas should receive a minimum of 40 lb K_2O/acre/year. Just like with phosphorus, 100-ft cells were combined to form larger units with increased grid size. Again, the larger units were assigned a soil test level based on the average of cells going into that unit. A summary of results from this exercise are shown in Table 5 for the 100-ft, 200-ft, 300-ft, 400-ft, 500-ft and 1000-ft grid size. Much less variation in applied K fertilizer was observed for potassium. The lowest K application amount was observed at the 300-ft grid (2.07 acres) while the highest application would again occur with the 100-ft grid size.

Table 4: Summary of potassium needs based on 100-ft grid samplings (0.23 acre) for Tribbett Satellite Farm, DREC, Mississippi State University

LEVEL	RATE	CELLS	AREA	FERTILIZER
	(K_2O/Acre)		(Acres)	(lb K_2O)
VL	120	0	0.00	0
L	90	68	15.61	1405
M	60	57	13.09	785
H	40	72	16.53	661
H+	0	3	0.69	0
TOTAL		200	45.92	2851

Table 5: Summary of potassium fertilizer needs based on grid sample size for 45.92 acre block On the Tribbett Satellite Farm, DREC, Mississippi State University

GRID	CELLS	K	K_2O	0-0-60
(ft)	(acres)	(lb/block)	(lb/block)	(lb/block) (%)
100	0.23	2367	2851	4752 (108)
200	0.92	2264	2727	4546 (104)
300	2.07	2184	2631	4385 (100)
400	3.67	2287	2755	4592 (105)
500	5.74	2335	2813	4688 (107)
1000	22.96	2287	2755	4592 (105)
AVERAGE		2287	2755	4592

For both phosphorus and potassium soil tests, variations in application for the test area vary with grid sample size indicating that there may not be an optimum size. While this exercise was completed to illustrate a point, it becomes obvious that the more samples one has from a specific area, the better the odds of identifying spatial variation in the field. One must also recognize that soil tests are only as good as the sample provided. Zone sampling has been suggested as a mechanism for providing a better picture while other argue that the grid make more since. There is no doubt that spatial variability in a select field can be detected with detailed soil sampling and mapping but the interpretation and ultimate use of the data is open for debate. Composite sampling may mask problem areas which could be delineated by detailed mapping. However, the intensity of soil sampling will always be limited cost and must be weighed against the benefits gained from more precise fertilizer application and use.

Summary and Conclusion

The question that has yet to be answered deals with the accuracy of composite samples and the grid size in general. To further evaluate the exercise, Figure 3 has been taken directly from the phosphorus map. When comparing the 100-ft grid (0.23 acre) with the 300-ft grid (2.07 acres) and the soil test values assigned based on the average of nine cells. In Unit 3, the average soil test P is in the L range when averaged across the nine cells comprising that unit. If the average were applied, the correct rate of P fertilizer would be applied to only 4 of 9 cells. If the same comparison is made of Unit 6 where the average is H (no fertilizer applied), based on the 100-ft cell, the correct fertilizer rate

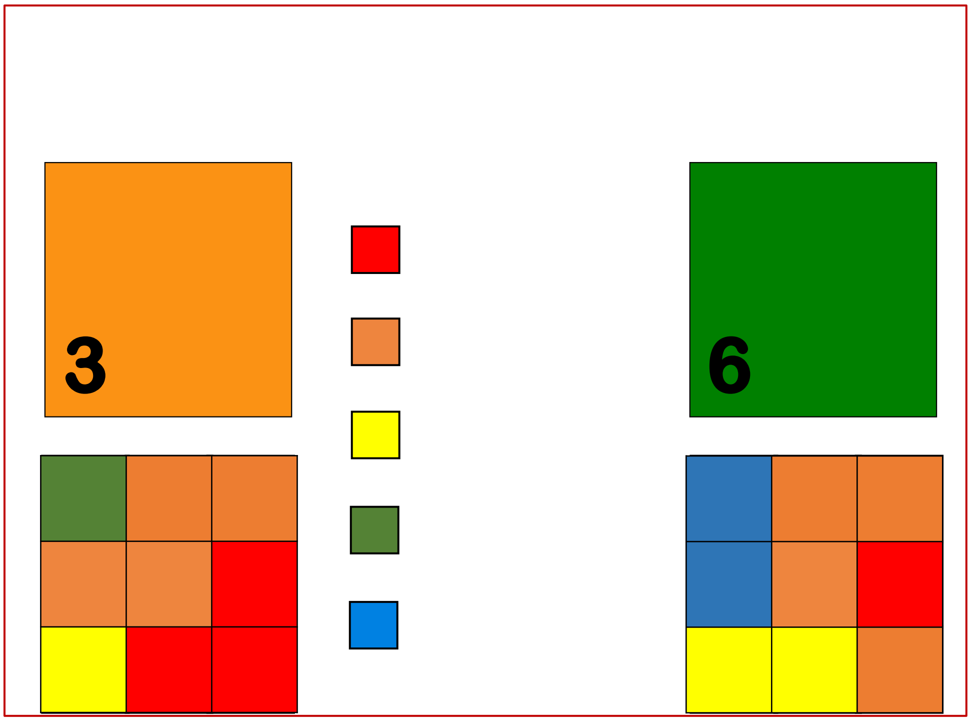

Figure 3. Soil test phosphorus levels based on 100-ft grid and 300-ft composite at the Tribbett Satellite Farm, DREC, Mississippi State University
Soil Analyses completed by Soil Testing and Plant Analysis Laboratory

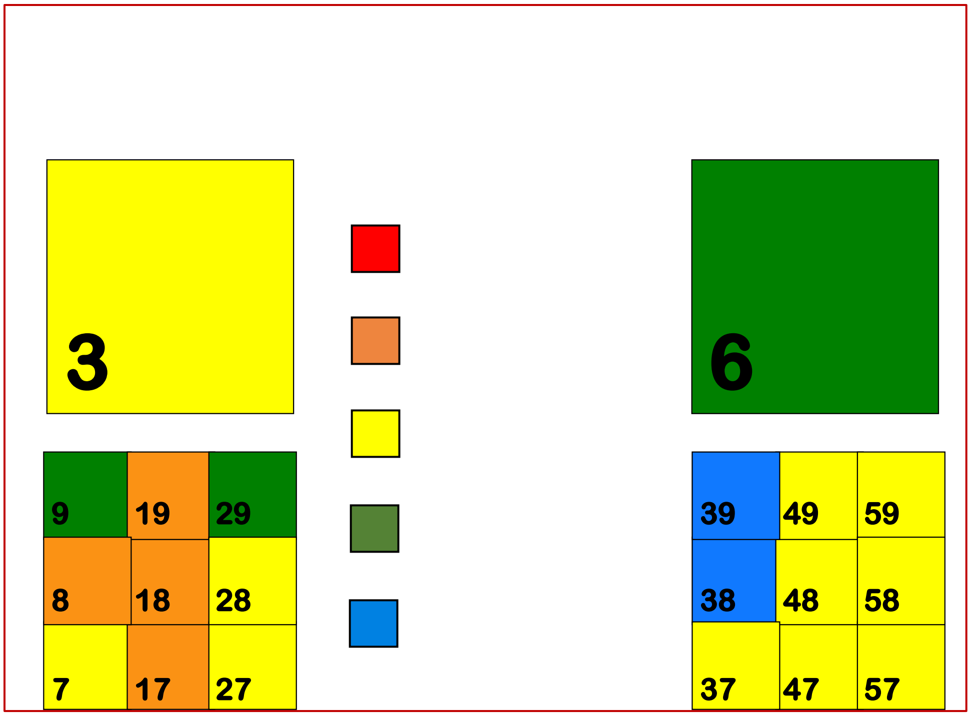

Figure 4. Soil test potassium levels based on 100-ft grid and 300-ft composite at the Tribbett Satellite Farm, DREC, Mississippi State University
Soil Analyses completed by Soil Testing and Plant Analysis Laboratory

would be applied 0 of 9 times. The average was different from all nine cells making up the unit. The range was from VL to H+ within a 300-ft grid. Figure 4 was taken from the same cells of the potassium map and used to make the same comparisons. For Unit 3 (Figure 4), the average was correct in 3 of 9 cells while 4 cells would receive too little fertilizer and 2 cell would receive too much. With Unit 6 (Figure 4), the average would be incorrect 9 of 9 times with 7 cells being under fertilized and 2 cells over fertilized.

With the above illustrations, one must realize that no two situations are the same or even similar. Variable rate application technology does make it possible to apply varying rates of nutrients while on the move across the field. Whether the costs of acquiring the information and the costs of application can be overcome with improved yields or improved efficiency has yet to be sufficiently determined. The use of precision application may not decrease or increase the amount of fertilizer nutrients needed but should increase the overall productivity of a field. Has the question been answered as to whether grid sampling is science, mystery, or magic. From this researcher's perspective…maybe a little of all three.