OKLAHOMA

Small-Scale Variation in Soil Test Phosphorus and Bermudagrass Yield

By W.R. Raun, J.B. Solie, G.V. Johnson, M.L. Stone, R.W. Whitney, H.L. Lees, H. Sembiring and S.L. Taylor

Precision farming has the potential to become an integral part of production agriculture, impacting growers, fertilizer dealers, equipment manufacturers, environmental groups, and others. Recent work in precision agriculture has used yield maps as keys to identifying spatial variability in crop production systems without generally questioning the resolution at which yield maps are generated. Present day yield maps that use the Global Positioning System (GPS) are generated at a resolution of approximately 30x30 ft. The exact size is defined by the width of the combine header. In general, the 'precision farming' resolution has not been driven by what was agronomically needed or economically advantageous, but by what was technologically available.

A recent Oklahoma study looked at the challenges of determining variability of fertility in small areas of fields and adapting management accordingly. More research is needed to develop accurate and practical methods for measuring variability in fields.

Field element size can be defined by the area which provides the most precise measure of the available nutrient where the level of that nutrient changes with distance. Our recent research has indicated that variable rate technology which treats field elements greater than 21 sq. ft. will likely not optimize fertilizer nitrogen (N) inputs while having the potential for misapplying fertilizers as a result of using too coarse a grid.

In conventional production systems, field element size should theoretically meet the following criteria;

1. Identify the smallest practical resolution where cause and effect relationships can be measured.
2. Identify the precise resolution where variances between paired samples of the same size (area) become unrelated (use of semivariograms).

Two established bermudagrass pastures were identified and a visually homogenous 7x70 ft. area was selected for intensive forage and soil sampling. For the past ten years, no fertilizer was applied at either site and bermudagrass has been grown continuously. However, the Burneyville site has been used for infrequent cattle forage. Both sites were considered to be N responsive. Each 7x70 ft. area was partitioned into 1x1 ft. plots (490 subplots), subsequently harvested and soil sampled (8 cores/plot 0-6 inches deep). Soil samples were analyzed for pH, phosphorus (P) and potassium (K).

Prior to forage harvest, spectral radiance readings were assessed from each 1x1 ft. subplot using a sensor developed at Oklahoma State University, and which has since been modified for use on a variable rate N applicator. Photodiode detectors and interference filters for red (671 ± 6 nm), green (550 ± 6 nm) and near

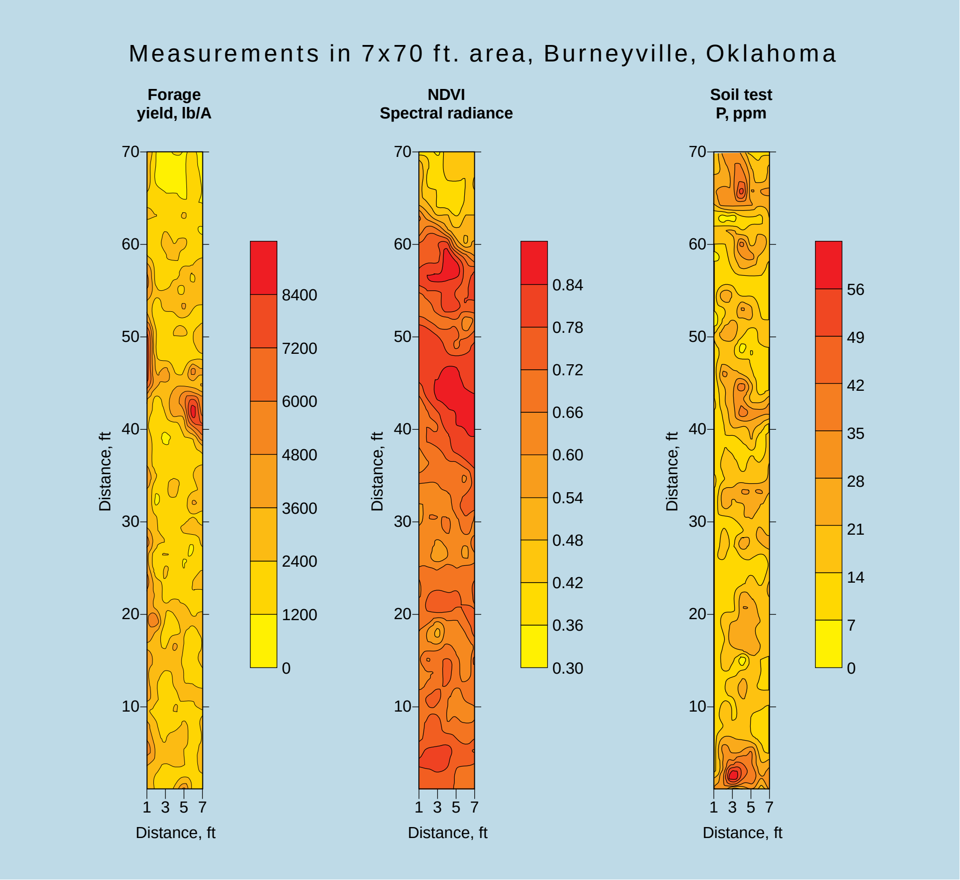

Figure 1. Surface contour maps of bermudagrass forage yield, spectral radiance measurements... normalized-difference-vegetation-index (NDVI)...taken prior to harvest, and soil test P from a 7x70 ft. area sampled on a 1x1 ft. grid, Burneyville, Oklahoma.

infrared (NIR, 780 ± 6 nm) spectral bands were used. The normalized-difference-vegetation-index (NDVI) was calculated where NDVI = (NIR-red)/(NIR+red).

At both locations, bermudagrass forage yield harvested from 1x1 ft. plots ranged from less than 1,000 to greater than 9,000 lb/A equivalent. This is illustrated in a surface contour map at Burneyville (**Figure 1**).

Finding a 10-fold difference in yield within a 490 sq. ft. area at both sites was alarming considering that the precision error in estimating yield (precision of scale for wet and dry weights and harvest area error) was small. As can be seen in the NDVI contour map from spectral data collected from each 1x1 ft. plot at Burneyville, this parameter resulted in similar patterns as that noted for forage yield. Other researchers have also demonstrated strong correlation between NDVI and plant biomass.

Mean soil test P values were 18 and 42 parts per million (ppm) at Burneyville and Efaw, respectively (**Table 1**). Similar to forage yield, variability in soil test P within the 490 sq. ft. was large, as is illustrated at Burneyville (range of 3 to 124 ppm, **Table 1** and **Figure 1**). The mean soil test P of 18 ppm at Burneyville was in excess of 80 percent sufficiency for bermudagrass production. At this level, only 20 lb of P_2O_5 fertilizer would have been recommended. However, larger fertilizer P rates would have been required when observing micro-scale variability evidenced in significant portions within the 490 sq. ft. area. Fertilizer P recommendations based on the extractable P levels reported would have ranged from 0 to 60 lb P_2O_5/A at Burneyville. Although graphic data are not reported, soil pH ranged from 4.37 to 6.29 within the 490 sq. ft. area at Burneyville. The mean soil pH was near 5.5 at both sites, but several values were below 4.5 at Burneyville (**Table 1**). At this pH, aluminum (Al) and/or manganese (Mn) in soil solution can increase to toxic levels. Thus, lime would be required in these areas to alleviate the toxicity. Similar variability in soil test and forage yield parameters has been found at other monitored sites.

The 7x70 ft. areas that were sampled on a 1x1 ft. grid in this research were used to identify the resolution where real differences in both soil test and yield parameters could be detected. They were not intended to be 'representative' of the range in variability found in each field, but rather indicators of the fixed area where 'real' differences can be found within that field. At present, our research is showing that field element size (measure of the available nutrient where the level of that nutrient is related with distance) will seldom exceed 21 sq. ft.

Finally, it is important to note that when farmers collect 15 to 20 random cores (0 to 6 or 0 to 8 inch depth) from a field, the composite sample often provides an accurate estimate of the mean soil test nutrient level in that field. However, the mean soil test nutrient level does not address the variability encountered in that field. Because micro-variability has been found to be so great in some fields, soil sampling the variability in those fields would not be affordable. For precision agriculture to treat most of the variability encountered in such agricultural fields, accurate and inexpensive indirect measures will be needed that account for the variability. BC

Acknowledgments: This work was supported in part by the Samuel Roberts Noble Foundation, Ardmore, Oklahoma and by PPI/FAR. The authors are with the Department of Agronomy, Oklahoma State University.

TABLE 1. Mean, standard deviation, minimum and maximum values for forage yield and soil analyses from 1x1 ft. plots, Burneyville and Efaw.

Burneyville	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Forage yield, lb/A	2,593	1,420	218	9,598
Soil pH	5.44	0.22	4.37	6.29
Soil P, ppm	18.4	9.6	3.1	124.1
Soil K, ppm	130.2	37.6	13.0	262.0
NDVI	0.685	0.119	0.331	0.909
Efaw	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Forage yield, lb/A	6,556	3,448	1,090	21,379
Soil pH	5.81	0.19	5.37	6.34
Soil P, ppm	41.8	9.6	15.2	63.7
Soil K, ppm	131.4	38.4	12.0	301.0
NDVI	0.530	0.044	0.373	0.667