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The Impact of Soil Sampling Errors on Variable Rate Fertilization

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ABSTRACT

Variable rate fertilization of an agricultural field is done taking into account spatial variability in the soil's characteristics. Most often, spatial variability in the soil's fertility is the primary characteristic used to determine the differences in fertilizers applied from one point to the next. For several years the Idaho National Engineering and Environmental Laboratory (INEEL) has been developing a Decision Support System for Agriculture (DSS4Ag) to determine the economically optimum recipe of various fertilizers to apply at each site in a field, based on existing soil fertility at the site, predicted yield of the crop that would result (and a predicted harvest-time market price), and the current costs and compositions of the fertilizers to be applied. Typically, soil is sampled at selected points within a field, the soil samples are analyzed in a lab, and the lab-measured soil fertility of the point samples is used for spatial interpolation, in some statistical manner, to determine the soil fertility at all other points in the field. Then a decision tool determines the fertilizers to apply at each point.

Our research was conducted to measure the impact on the variable rate fertilization recipe caused by variability in the measurement of the soil's fertility at the sampling points. The variability could be laboratory analytical errors or errors from variation in the sample collection method.

The results show that for many of the fertility parameters, laboratory measurement error variance exceeds the estimated variability of the fertility measure across grid locations. These errors resulted in DSS4Ag fertilizer recipe recommended application rates that differed by up to 138 pounds of urea per acre, with half the field differing by more than 57 pounds of urea per acre. For potash the difference in application rate was up to 895 pounds per acre and over half the field differed by more than 242 pounds of potash per acre. Urea and potash differences accounted for almost 87% of the cost difference. The sum of these differences could result in a $34 per acre cost difference for the fertilization.

Because of these differences, better analysis or better sampling methods may need to be done, or more samples collected, to ensure that the soil measurements are truly representative of the field's spatial variability.

Keywords: fertilization, variable rate, soil fertility, sampling error

INTRODUCTION

We have been developing and refining the Decision Support System for Agriculture (DSS4Ag) over the past ten years. Until recently the refinements have focused on a decision support system for generating spatially variable fertilizer recipes based on the economically optimum production of the crop, such as potatoes, small grains, corn, or cotton. Two years ago we began to extend the capability of the DSS4Ag to develop a variable-rate fertilizer recipe for the simultaneous production of both grain and straw in support of the growing interest in agricultural crop residues as a bioenergy feedstock (DOE Roadmap, 2003).

The DSS4Ag uses as input a site-by-site description of the existing spatially variable soil fertility, along with historic databases describing site-specific soil fertility data and resultant yield data, and current data on fertilizer costs and compositions, as well as a forecast market price for the crop at harvest. The DSS4Ag outputs a site-specific fertilizer recipe defining the economically optimum mix and amounts of each fertilizer to be applied at each site.

In this paper we report on the differences in soil laboratory analyses, and differences in the fertilizer recipe generated by the DSS4Ag that result from differences in the input describing the soil fertility.

MATERIALS AND METHODS

The Research Fields

In order to measure the soil laboratory analytical errors, errors from variation in the soil sample collection method, or errors in measuring the soil sample point locations, we collected repeated soil samples in three different ways as part of our ongoing bioenergy feedstock research. This field research was conducted on two different private farms just west of Idaho Falls, Idaho, in Field 1 in 2002 and in Field 2 in 2003 (Figure 1). Field 2 is about 4.8 miles northwest of Field 1.

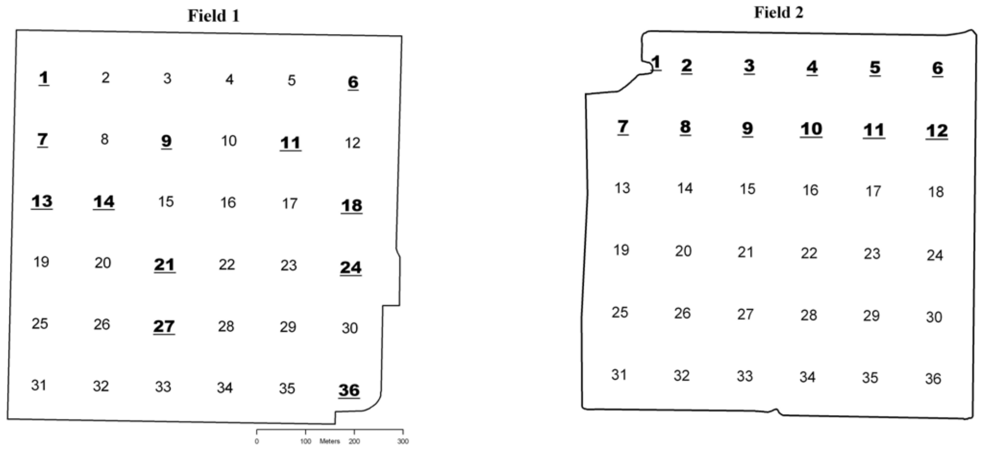

Fig 1. Study fields, showing soil sampling locations. Multiple samples were collected at the locations in bold underlined.

Soil Sampling

Triplicate samples

In 2002 we collected soil samples across a 154 acre field (Field 1, Figure 1) at each location as part of the DSS4Ag bioenergy feedstock research. Samples were collected with a soil probe from the top 12 in. of topsoil. At each location, approximately 10 cores were collected from within about 3 ft. of the point, and were thoroughly composited in a pail. From the composite, about 1 lb. was placed in a sampling bag marked with the location number. At twelve randomly selected sampling points the composited soil was divided into three sampling bags. These bags were marked with different blind location numbers unknown to the laboratory. All samples were submitted to a certified soil analytical laboratory for analysis.

The laboratory's analytical results from these triplicate samples have been used to measure statistically the variability due to the laboratory's error.

Repeated samples

In 2003 we collected soil samples across a 148 acre field (Field 2, Figure 1) at each location prior to fertilization as part of the ongoing DSS4Ag bioenergy feedstock research. At each location, approximately 10 cores were collected with a soil probe from the top 12 in. of topsoil from within 3 ft. of the point, and were thoroughly composited in a pail. About 1 lb. of the composited soil was placed in a sampling bag marked with the location number. In addition, at the twelve northernmost sampling locations the process of collecting about 10 cores, compositing, and placing about 1 lb. of composite in a sampling bag, was repeated two more times. Therefore, at the northernmost 12 locations we had three soil samples that were individually collected. These samples were marked with blind location numbers unknown to the laboratory, and submitted for blind analysis along with the other samples.

The laboratory's analytical results from these repeated samples have been used to statistically determine the variability due to the different samples collected from within 3 ft. of the sample location.

The maximum and minimum values for individual soil fertility parameters from these 12 sample sites were also used as input to the DSS4Ag to estimate the extreme bounds of the differences in the fertilizer recipe due to differences among samples.

RESULTS

Triplicate samples

Ideally we would like the laboratory error to be as small as possible, with the ultimate being small enough to ignore for the purposes at hand, making fertilization decisions.

It was immediately clear from cursory analysis of the triplicate data that the variance of the triplicate measurements was not constant across grid locations, there was no discernable pattern across the grid, and the variances did not seem correlated with the grid means. Figures 2, 3, and 4 illustrate the differences across grid locations by plotting the minimum and maximum values for the key variables N, P, and K.

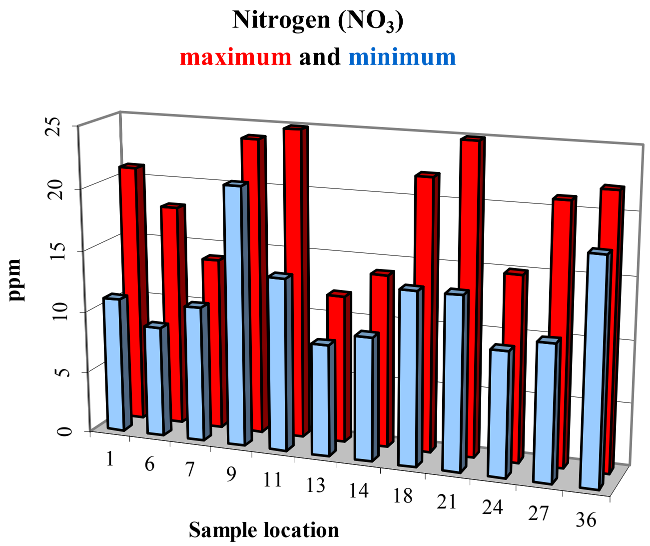
Nitrogen (NO_3)
maximum and minimum

Fig. 2. Nitrogen minimum and maximum values for triplicate samples by Field 1 grid location.

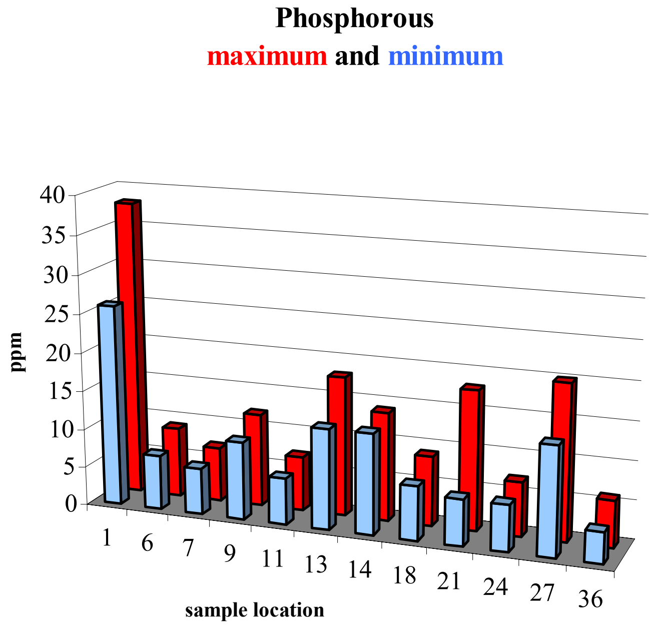
Phosphorous
maximum and minimum

Fig. 3. Phosphorous minimum and maximum values for triplicate samples by Field 1 grid location.

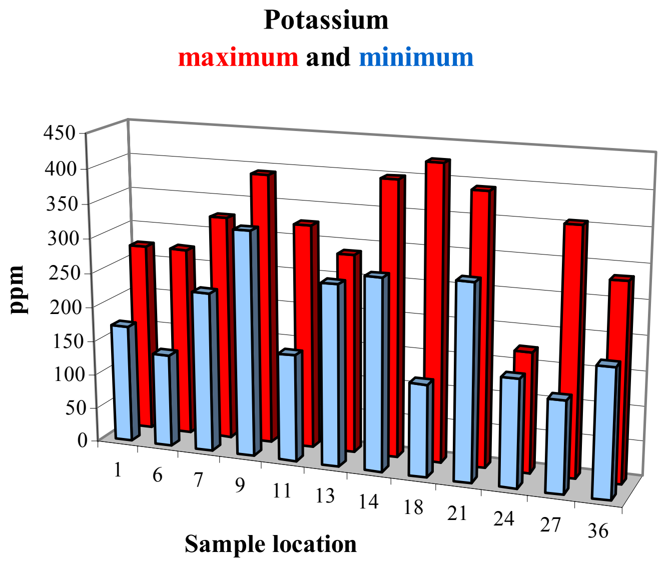

Fig. 4. Potassium minimum and maximum values for triplicate samples by Field 1 grid location.

Repeated samples

Figures 5, 6, and 7 plot the mean, maximum and minimum repeated sample measurement results for the key fertility variables N, P, K. The values are plotted on similar scales as in Figures 2, 3, and 4 for the triplicate data so that the fertility levels can be easily compared in the two different fields.

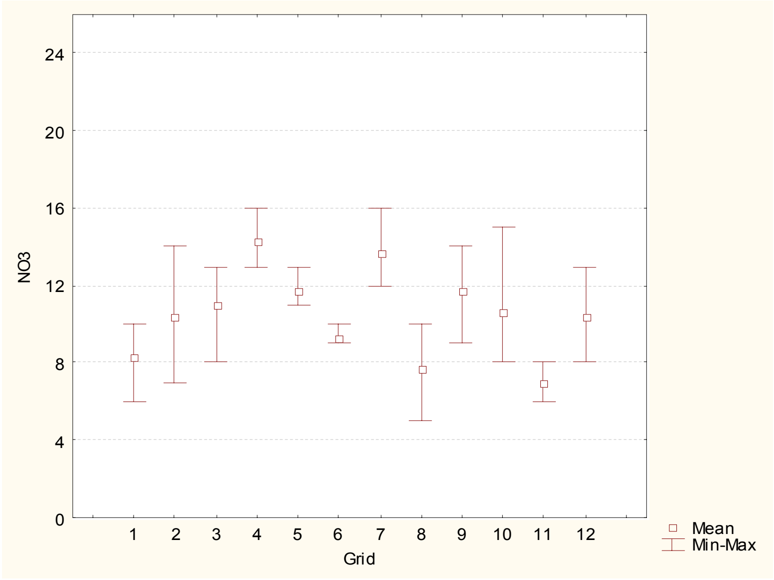

Fig. 5. Nitrogen mean, minimum, and maximum values for repeated samples by Field 2 grid location.

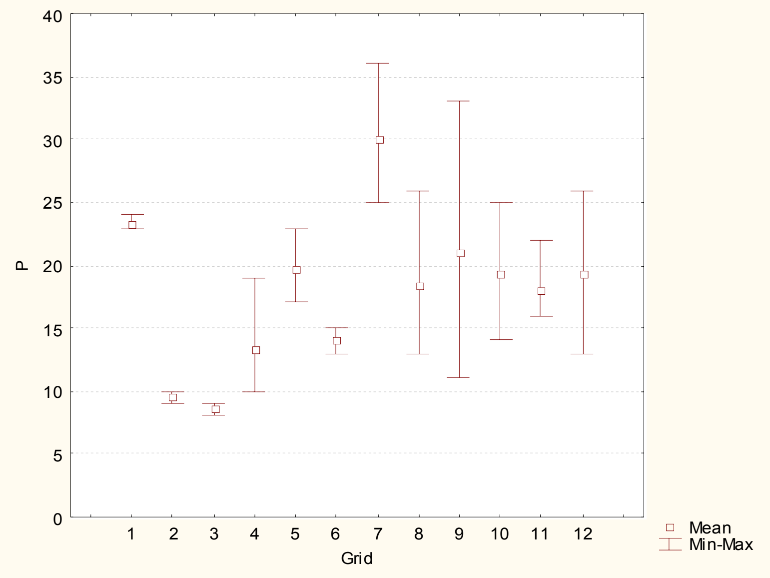

Fig. 6. Phosphorous mean, minimum, and maximum values for repeated samples by Field 2 grid location.

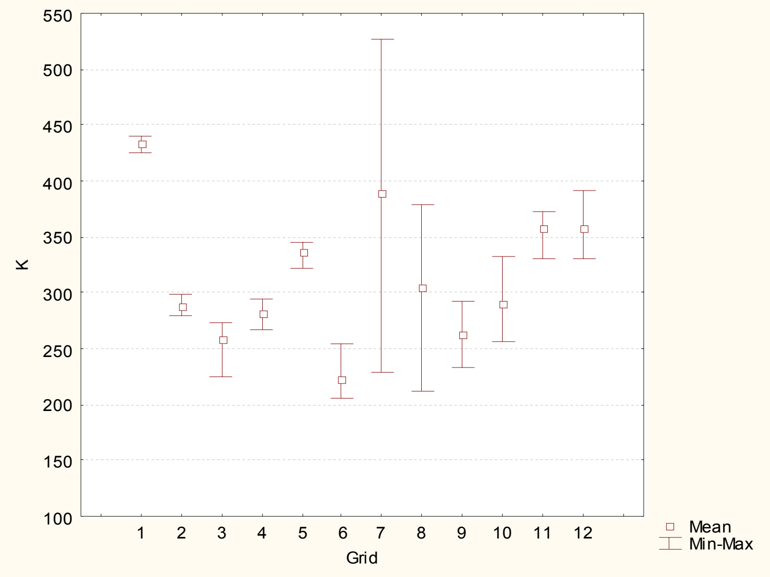

Fig. 7. Potassium mean, minimum, and maximum values for repeated samples by Field 2 grid location.

Table 1 compares the repeated measurement error variability (the average of the variances) to the variability of the fertility variables across grid locations (the variance of the means). The results in Table 1 show that for most of the fertility measures, repeated measurement error exceeds the estimated variability across grid locations. This is an indication that the observed variability in the repeated measures is primarily due to laboratory measurement error.

Table 1. Comparison of repeated measurements variability to variability of fertility measures across grid locations.

Fertility parameter	Average of variances	Variance of means
pH	1.89E-02	1.62E-02
Salts	2.61E-03	3.76E-03
Na	8.05E+01	6.18E+01
CEC	3.61E-01	1.93E-01
Lime	7.32E-01	6.05E+00
%OM	7.50E-03	1.56E-02
N	5.53E+00	3.08E+00
P	2.68E+01	2.58E+01
K	2.99E+03	2.73E+03
Ca	1.23E+05	2.50E+05
Mg	1.15E+03	1.16E+02
S	1.86E+00	2.39E+01
Zn	1.06E-01	8.51E-02
Fe	4.36E+01	1.55E+01
Mn	3.39E+00	1.28E+00
Cu	1.47E-02	1.65E-01
B	6.39E-03	2.21E-03

Impact on fertilizer recipes

For the north third of Field 2 (46.2 acres), using the repeated soil samples collected in spring 2003 from the adjacent 12 sampling locations, we created an input to the DSS4Ag using the minimum soil fertility parameters at each point and another input using the maximum values. The DSS4Ag then generated an economically optimum fertilizer recipe based on the minimums (low recipe), and another based on the maximums (high recipe).

Table 2 shows the differences in the fertilizers' amounts applied and costs for the high and low recipes. The variability in the reported soil analyses could result in a predicted input cost difference of as much as $34/acre to the grower. Urea and potash differences accounted for almost 87% of the cost difference.

Table 2. Predicted differences between high recipe and low recipe.

Fertilizer	**Urea**			**Ammonium Phosphate**			**Potash**			**Ammonium Sulfate**			**Urea/Boron**		
	Ave lbs/acre	Amt. (lbs)	Cost	Ave lbs/acre	Amt. (lbs)	Cost	Ave lbs/acre	Amt. (lbs)	Cost	Ave lbs/acre	Amt. (lbs)	Cost	Ave lbs/acre	Amt. (lbs)	Cost
High recipe	40	1833	$225	0	0	$0	4	199	$17	58	2675	$214	6	271	$122
Low recipe	98	4532	$555	0.2	9	$1	265	12230	$1064	64	2947	$236	15	679	$305
Low-High	58	2699	$331	0.2	9	$1	260	12031	$1047	6	272	$22	9	408	$184

In this study urea application rates differed by up to 138 pounds per acre in some locations because of the differences in the soil analytical results (Figure 8). For 50% of the field area an application rate of at least 57 pounds of urea per acre difference was predicted.

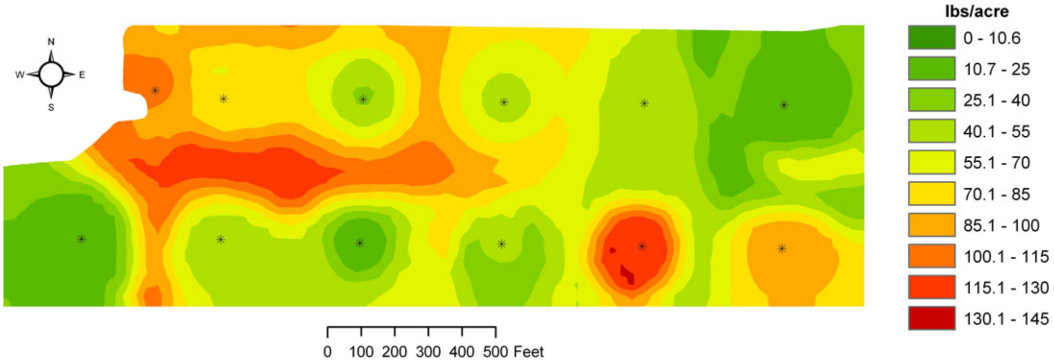

Fig. 8. Spatial difference in high and low DSS4Ag recipes for urea.

The potash application rate difference (Figure 9) between the high and low recipe predictions was as high as 895 pounds per acre. For 50% of the field area an application rate of at least 242 pounds of potash per acre difference was predicted.

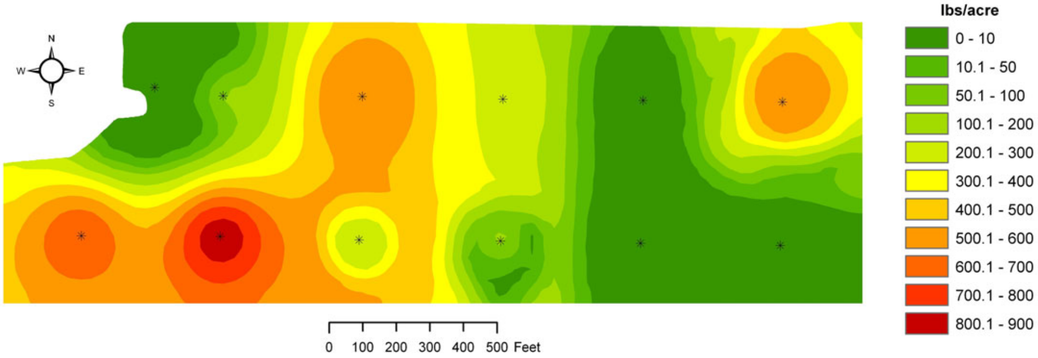

Fig. 9. Spatial difference in high and low DSS4Ag recipes for potash.

CONCLUSIONS

The wide variation in the reported analytical results from the triplicate samples strongly suggests that the laboratory analyses often give widely varying values for the same soil sample. This is supported by data showing that for most of the fertility measures, repeated measurement error exceeds the estimated variability across grid locations.

The impact of these analytical errors is extremely important when the analytical results are used as input to a decision support system that generates spatially variable fertilizer recommendations.

Our results suggest that the fertilizer recipe costs could change by as much as $34 per acre under the conditions of our study, and the difference in the amount of urea recommended could vary by over 57 pounds per acre for at least half the area. For potash at least half the area’s recommendation difference was between 242 and 895 pounds per acre.

Due to the importance of the soil fertility measurement accuracy on the recipe development, greater effort may need to be taken to ensure that the soil measurements are truly representative of the field's spatial variability. This may require better analysis, sampling methods, or number of samples.

ACKNOWLEDGEMENTS

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