

DEVELOPING FIELD SAMPLING PROCEDURES

Field sampling procedures for soil sampling or pest scouting in a crop consulting business must meet two overarching goals:

- Accurate estimation of the parameter being measured
- Efficient use of resources

These goals often exist in tension. That is, a more accurate estimate most generally necessitates greater use of a consultant's labor, equipment, and/or analytical resources. For this reason, time spent optimizing field sampling procedures can improve both the quality of information generated and the profitability of a consulting enterprise.

Sampling Patterns

One of the most abused terms in IPM is the word "random." We are not by nature random beings, and thus when we go out and try to "stop at random locations in a field" our attention is inevitably drawn to interesting areas or plants. Whether we realize it or not, we introduce a bias into our sample.

In a truly random sample, the location of each point is determined independently without bias. Directions from an IPM class I once took read "multiply the dimensions of the field (paces, meters, rows, etc) by a random decimal between zero and one obtained from a random number table or from a random number generator on a computer." These points are then plotted and the scout navigates to each one in turn. A truly random sample will return the greatest accuracy for a given sample size, Especially where pests are distributed in a clustered fashion through a field. Some GPS-based field logging software will simplify this process considerably, nevertheless, in my opinion this approach finds its most appropriate application in academic research situations, *not* in a commercial crop consulting business.

Systematic sampling provides something of a compromise between the above approaches. Scouts walk a pre-determined number of paces and select a sample based on some non-subjective criterion (e.g. the nearest plant to the tip of your right boot). This approach does not measure clustered data as efficiently as a truly random sample, but it is more time-efficient and it minimizes the problem of bias inherent in more subjective methods.

Quantitative vs. Non-Quantitative Pest Rating Scales

Non-quantitative approaches have their place. When pest infestations are distributed in a highly irregular, clustered pattern in a field (e.g. weed patches) systematic or random sampling call for extremely large sample sizes to estimate mean infestations, and still don't return any depiction of the spatial distribution of the problem. In situations like,

this an intuitive judgement by a well-experienced consultant is a far more efficient sampling approach than a quantitative method (e.g. counting weed numbers in 30 ft of row).

Nevertheless, quantitative approaches should be used wherever feasible. Scouting programs which rate disease infestations on a low-medium-high scale may be adequate for some IPM systems, but quantitative methods are often practical and far more accurate. Scouting approaches which use standardized rating scales to estimate disease or insect damage (e.g. the percent leaf area infected) reduce subjectivity and permit better comparisons between scouts and through time. In our experience, they also manage to detect trace infestations (e.g. early wheat leaf rust) which the low-medium-high approaches tend to miss. Many standardized rating scales are available from the American Phytopathological Society and other sources. Software for training scouts in the use of some of these scales was developed by F.W. Nutter of Iowa State Univ. and are available on the internet at:

www.ag.iastate.edu/departments/plantpath/faculty/fnutter/fnutter.html.

Quantitative scales are essential when making statistical comparisons of sampling methods. Low-medium-high scales are sometimes converted to numerical values, but since they are not by nature quantitative, this is not really appropriate. For this reason, determining appropriate sample sizes, or measuring the accuracy or reproducibility of such systems becomes problematic statistically.

Sample Size Determination

An adequate sample size (n) can be estimated from 3 values:

- w = the +/- range of accuracy considered acceptable by the consultant
- z^2 = a probability factor that reflects how often you need your estimate to fall within the above accuracy range.

Confidence

<u>level</u>	<u>z^2</u>
99%	6.6
95%	3.8
90%	2.7
80%	1.7

Other z values can be looked up in any statistical reference.

- σ^2 = variance, a measure of the variability of the value being measured.

The statistical formula reads:

$$n = z^2 \sigma^2 / w^2$$

Note that the field size does not enter into the equation. A common, but false, assumption many people make is that larger fields need larger samples. This is only the case if larger fields also have more variability

As an example, to determine the number of cores needed at each site when grid sampling for soil nitrates, Centrol consultants decided that an acceptable error range was +/- 20% of the true mean value, and that their estimates could fall outside this range 20% of the time. In field 96V1-N 36 cores were taken and tested individually. Their mean was determined to be 36 lbs/a with a variance of 211. The optimum number of cores could be calculated as follows:

$$1.7*211/(36*.2)^2 = 7 \text{ cores}$$

The raw data for this calculation as well as other fields sampled in the same project are attached as an Excel file: *samplesize.xls*.

If the value being estimated is a proportion rather than a quantitative variable (e.g. the proportion of diseased plants in a field) the same equation can be used. However, the variance (σ^2) varies with the proportion (P) as follows:

$$\sigma^2 = P(1-P)$$

For example, to determine the number of tillers you need to sample when estimating the number of wheat plants infected systemically with WSSMV (given an acceptable range of +/- 10%, a confidence value of 95% and an anticipated mean WSSMV incidence of 20%) the formula is calculated as follows:

$$3.8*0.2(1-0.2)/(0.1)^2 = 61 \text{ plants}$$

At very low and very high proportions, this variance will be much smaller, than at proportions near 0.5. This means in fields where values are very low or very high, you need less samples than in fields where values are nearer 50%. In the above example, the sample size drops to 34 if expected incidence is 10% rather than 20%. One solution in an IPM setting is to calculate the sample size when the proportion is at your treatment threshold, since values above and below this level do not generally need to be as accurate. Another approach is to take a relatively small initial sample in a given field, then decide for or against further sampling based on the proportion obtained in the initial sample.

Comparing Sampling Methods

Independent data sets are the only way to truly measure the accuracy of a sampling method. Avoid approaches which use estimated values as a standard of comparison (e.g. using interpolated values to compare GPS sampling methods). Another common error is use of “proxy” indicators (e.g. judging soil fertility sampling methods by their

resemblance to yield maps). Such comparisons may make sense intuitively, however, if you are comparing the accuracy of a given soil sampling or scouting method, the best measure is how well it matches the values of a similar data set (sampled independently), not whether it mimics the patterns of some other factor like yield, topography, soil type, etc.

Beware the correlation coefficient! This statistic measures how closely two variables are related. However, if one variable is *consistently inaccurate* it can be quite misleading. For example, say a scouting method consistently rates a disease too high. The r value of a plot of these values against a more accurate method may look quite good, but management decisions based on the method could, in fact, be disastrous. Another statistical measure of the accuracy of a given method vis-à-vis an independent data set is root mean square error, or RMSE. This statistic measures the deviation from the know values, not the deviation from a best-fit line as in a correlation analysis. RMSE is calculated as follows:

$$\text{RMSE} = \text{sqrt}(\left(\frac{\sum(v_i - v)^2}{n-1}\right))$$

Where v_i and v = observed and estimated values, and n = the number of samples.

An Excel spreadsheet with formulas for calculating RMSE and several examples is attached as: *RMSE.xls*

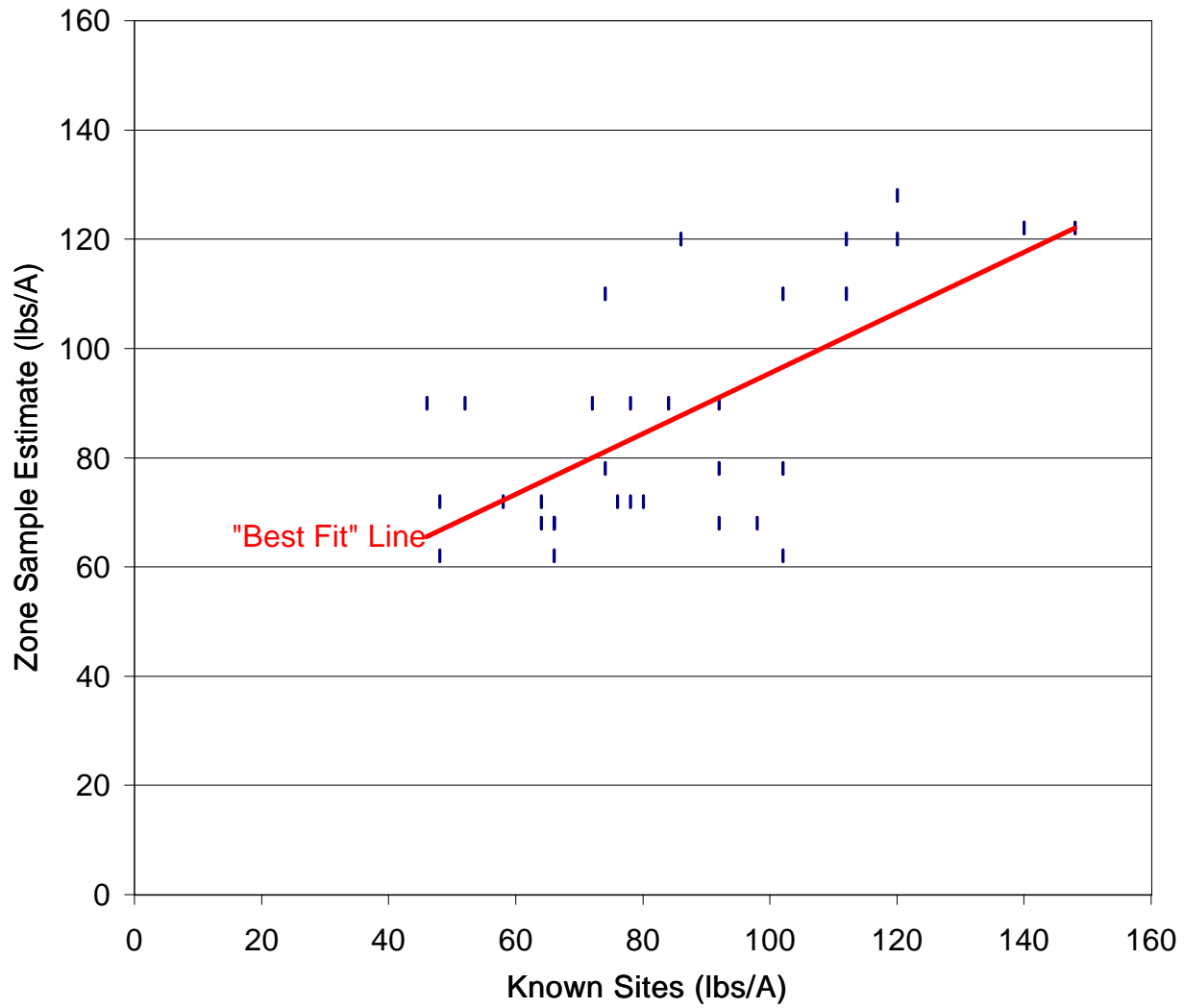
The RMSE value is expressed in the same units as the parameter being measured (e.g. lbs/acre or % leaf area). It does *not* carry a +/- sign, as does a correlation coefficient, so it will not tell you if the method being tested is consistently over or underestimating the true values. For this reason, it is always important to plot out points, and calculate regression coefficients as well as RMSE values.

Case Study: Accuracy of soil sampling methods and implications for fertility management in Michigan

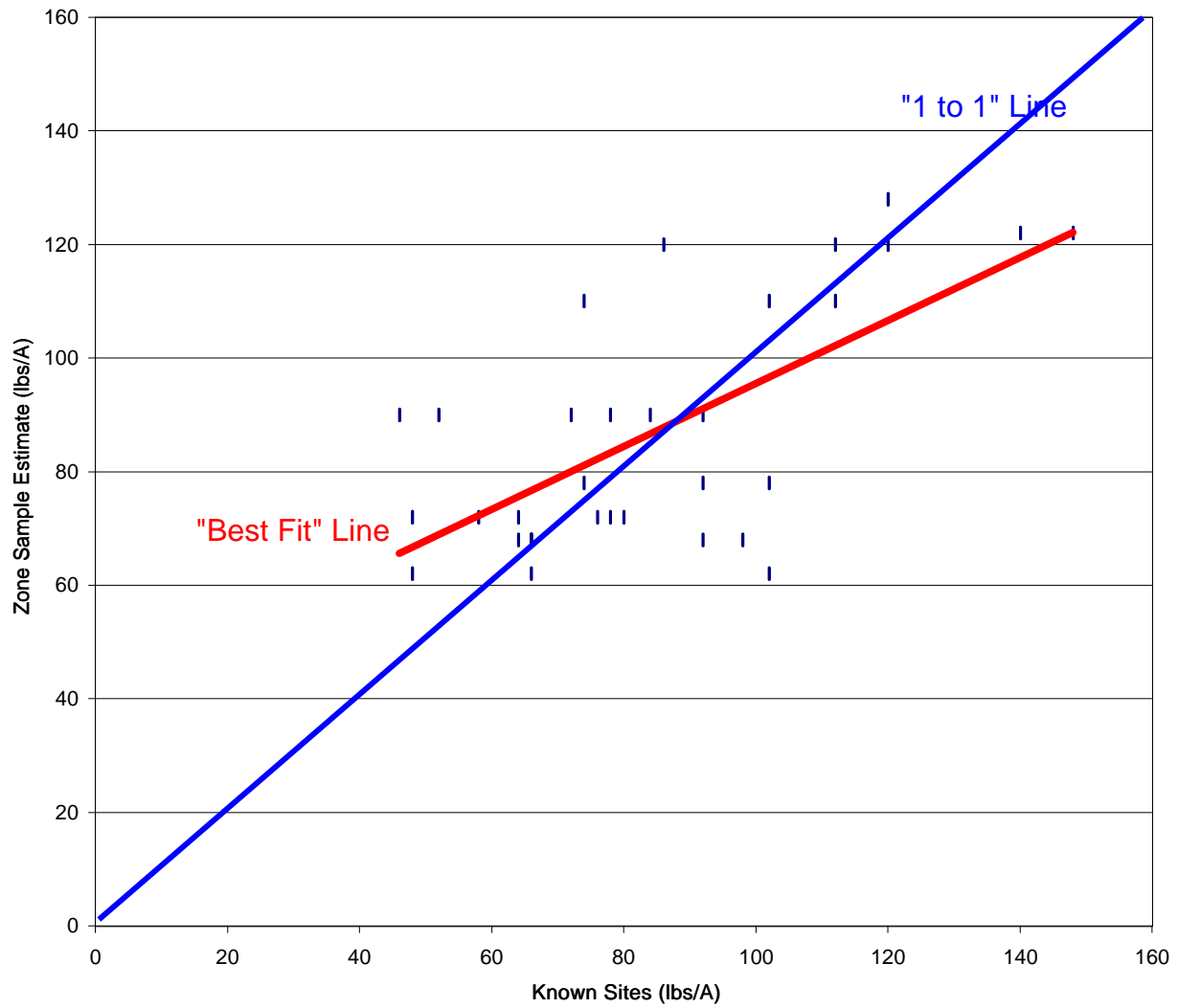
Soil fertility sampling methods were compared on 10 commercial farm fields in 1999. Independent samples were taken in each field using 2.5 acre grid point sampling (GS), 2.5 acre “smart” (directed) point sampling (SS), and 5-10 acre management zone (ZS) approaches. For each sample method, pH, phosphorus, potassium, organic matter, and nitrate values were mapped using several interpolation methods. The accuracy of interpolated values was compared at independent sample points taken from each field at the same time but at different locations.

Sample method accuracy varied from field to field, but SS and ZS sampling outperformed GS sampling overall. Sampling accuracy also varied widely depending on the fertility element being measured, with pH, phosphorus and organic matter showing a consistently greater spatial structure than potassium and nitrate.

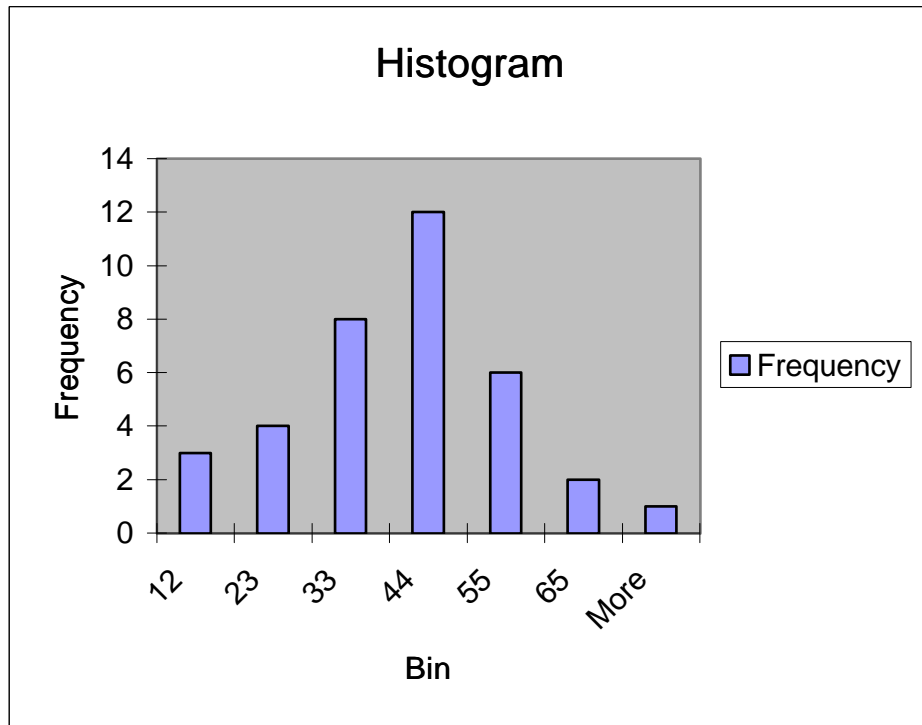
Phosphorus Sample Methods: Zone Sample Estimation of Known Sites



Phosphorus Sample Methods: Zone Sample Estimation of Known Sites



<i>Bin</i>	<i>Frequency</i>
12	3
23	4
33	8
44	12
55	6
65	2
More	1



<i>Bin</i>	<i>Frequency</i>
32	1
75	9
117	14
160	7
203	4
245	0
More	1

