Decision making for root disease control: a problem in reducing the nugget variance[1]

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Abstract: Root disease has the potential to cause large economic losses of agricultural production. Techniques are available for assessing the amount of pathogen present in soil using DNA assays. There is spatial variability in pathogen levels across fields and spatial methods would appear an obvious tool to use to map the incidence and distribution and as a basis to plan cropping programs. The information required for agronomic decisions has to be obtained in sufficient time and at an acceptable price for this to be a viable technique. Two examples where this is being used are wheat in large (40 to 100 ha) fields and potatoes grown in centre pivots. The largest difficulty encountered is obtaining a sampling scheme that produces a small nugget variance. Alternative sampling strategies are considered.

Keywords: Disease mapping, Agriculture and biodiversity

1. Introduction

Sampling fields for nutrient levels is used as a tool to optimize inputs and profits. More recently with the development of DNA based testing services, growers can now measure pathogen levels as an indicator of the disease potential of a field.

The challenges in sampling are to provide a 'fit for purpose' sampling scheme. Currently sampling is achieved by using cores of soil, or some alternative sampling scheme that provides a uniform representation of say the top 100 mm of soil. The sampling scheme has to be unbiased and it should have a small coefficient of variation and be cost efficient. The variation among samples arises from local variation (on a scale much less than 1 m) and also on a much larger scale (100 m or more). The local variation (nugget effect) represents variation between samples taken close together.

One method of reducing the local variation is to take many (up to 40) cores and combine them to form a composite sample. (Note that in some literature a core may be referred to as an aggregate sample and the composite as a cumulative sample). The

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composite samples represent an average of many core samples and hence should be more representative (have smaller coefficient of variation) of the local area.

Commonly cores to be composited are taken in some convenient predetermined pattern – perhaps in a circle around a vehicle. Alternatively samples could be taken in a straight line. The composite sample ideally should represent the range of variation near the nominated sampling point. Conventional wisdom says that increasing the distance apart of samples typically increases the variation between samples. A convenient and effective pattern for local sampling is therefore to take a series of small cores along a straight line. This suggests an alternative method of sampling where the sample is taken as a slot that is cut using a circular saw. Such a device is known as a linear sampler. It effectively takes samples from a line simulating the effect of taking many cores in a straight line.

A known source of local variation is the crop rows. These could hold increased levels of pathogen DNA compared to the inter-row. Furthermore there could be differences in nutrient status as fertiliser is usually applied with the drill. Differences between the row and inter-row are therefore to be expected. An alternative approach is to sample across the rows – this can be simply achieved with the linear sampler.

A trial has been carried out at two sites to explore variation in wheat. Each composite sample was assessed for phosphate (as representative of nutrient status) and for *Fusarium pseudograminearum* a stubble borne pathogen typically concentrated in the row, which causes to assess pathogen status of the fields. Data on six pathogens (including Black Dot, *Colletotrichum coccodes*) have also been collected from a range of potato crops that are grown using centre pivot irrigation. These data have been obtained from composite samples each representing one ha, with 40 cores used for every composite.

2. Materials and Methods

Linear sampler: A linear sampler was used to take some of the samples in the wheat field. The linear sampler essentially consists of s circular saw mounted on a carriage. The saw cuts a 10 cm deep slot in the soil (Figure 2) and output collected. Care was taken to ensure that the soil is representative of the 0 – 10 cm soil layer.

Core sampling of wheat fields: The wheat field was sampled at 26 sites in a systematic pattern to represent the area. At each sampling site, 10 cores were taken on the stubble row, 10 between the stubble rows, 10 on the stubble rows, a linear sample between the rows and two separate linear samples cross the rows.

Sampling of potato soil: Potatoes were grown under a centre pivot, with each pivot covering 30 – 50 ha. A 100 m square grid (1 ha) was superimposed on each centre pivot and a single composite sample was formed from 40 cores (12 mm diameter and 100 mm deep) taken along a W shaped transect from each ha. Each composite sample was assessed for potato root pathogens.

Variograms were constructed using the 'geoR' package (Ribeiro Jr. & Diggle 2001) using the 'variofit' function with 'max' set to half the observed maximum distance.

3. Results

Wheat root disease

There was effectively no correlation between of the pathogen DNA data obtained by the different sampling methods with correlations of the phosphate data ranging from 0.44 to 0.70 for samples taken within two metres of each other.

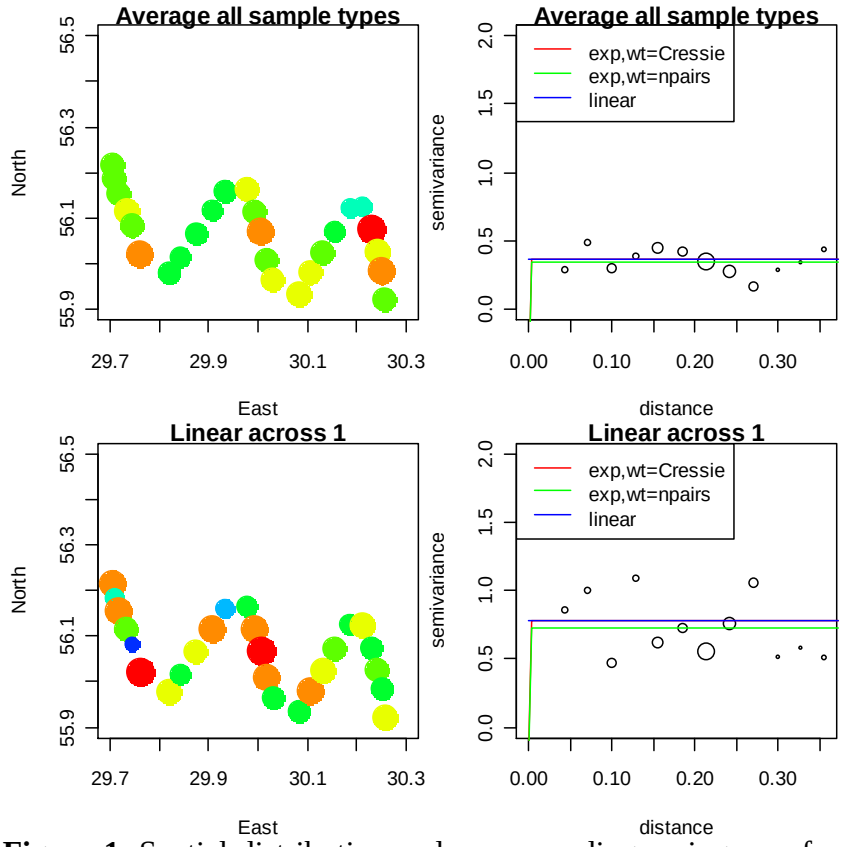

Figure 1: Spatial distribution and corresponding variograms for crown rot at Kybunga for average over a sample types series of samples of root disease (top half) and results from the linear sampler (bottom half). High amounts of disease are indicated by large red circles grading to low amount of disease shown as small blue circles. Each unit of distance is approximately 1 km.

Figure 1 shows the spatial distribution and estimated variogram for one series of linear samples. In most cases the variograms were not stable and the exponential fits would not converge for the inter-row samples (data not shown). Two sampling schemes (cores between rows and linear sampler on the row) showed a large nugget effect but also an increase in variance with distance. Although the data were expressed on a natural log scale, there were high estimates of the variance even when the samples were close together. This was despite using composite sampling or the linear sampler. Even when all six sampling types were averaged there was still no evidence of increasing variance with distance, but the estimated variance approximately halved (Figure 1).

Potato root disease

Potato disease shows some spatial patterning (but the sampling c.v. is still well over 50%). The commercial reality is that a farmer will use a maximum of four samples to represent a pivot of approximately 40 ha when making management decisions. Data from each ha are available for research purposes and these have been used to give a good approximation of the proportion of area that has pathogens levels that exceed an acceptable level. Detailed data are available to assess how well 4 samples can represent a pivot. A simulated commercial sampling was achieved by choosing a single ha from each quadrant of a pivot and obtaining its mean. The proportion of the pivot that exceeded a risk level was plotted against the mean DNA level of the four samples (Figure 2 right panel) and a logistic distribution was fitted. The results indicated that data from each of four 1 ha samples can be used to give a 'correct' answer in about 85% of cases despite the variability of the sampling.

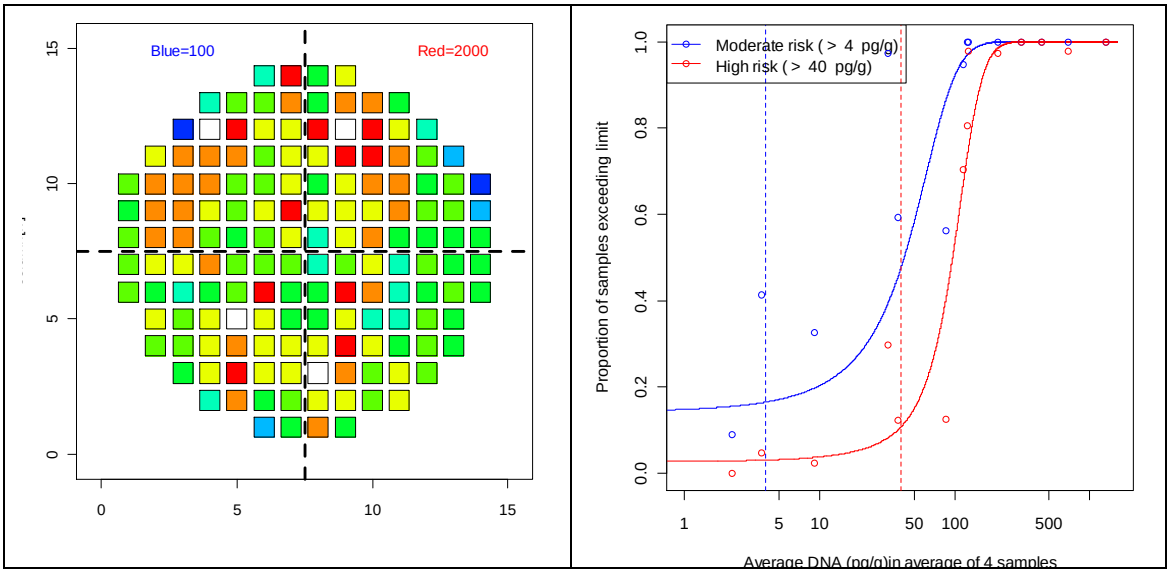

Figure 2: Left panel shows distribution of BD DNA in a typical pivot. Right panel indicates proportion of correct decision would have been made based on 4 samples. High and low levels indicate currently recognised limits of risk of commercial harm.

4. Concluding remarks

The number of samples available in a commercial agricultural application of the distribution of soilborne pathogens is far less than the number available for conventional spatial statistics. Furthermore, each sample has a very large variability (c.v. >50%). Despite these shortcomings, useful commercial decisions are currently being made.

The ongoing challenge to agricultural statisticians is how to take cost effective samples for the evaluation of root disease risk assessment, and to use our knowledge of spatial statistics to optimize this process. Nugget variance is a limiting use of spatial methods.

Reference

Ribeiro Jr., P.J. & Diggle .J. (2001) geoR: A package for geostatistical analysis. *R-NEWS*, **1** (2), 15-18.