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UNDERSTANDING SOIL PHOSPHORUS VARIABILITY WITH DEPTH FOR THE IMPROVEMENT OF CURRENT SOIL SAMPLING METHODS

T. M. C. Kaul, M. C. E. Grafton, M. J. Hedley & I. Yule

NZCPA, Massey University, Turitea Campus, Palmerston North
Correspondence: Therese Kaul E-mail: tmckaul@outlook.com

Abstract

Noise in soil test results can be reduced by measuring phosphorus below the top 3cm of soil from ground level. This is significant for improving current soil nutrient testing methods by allowing better geospatial predictions for whole paddock soil nutrient variability mapping for use in precision fertilizer application. In this study 200 cores were collected from predetermined grids at two trial sites at 'Patitapu' hill country farm in the Wairarapa. The sites were selected according to accessibility and slope- Trial 1 was a 200m x 100m grid located in a gently undulating paddock. Trial 2 was a 220m x 80m grid located on a moderate to steeply sloped paddock. Each grid had cores taken at intervals of 5m, 10m and 20m. Core sites were mapped out on a Landsat 8 image (NASA) of the Trial sites using ArcGIS 10.2 (ESRI, Redlands Ca.) prior to going into the field; these were then marked out using a LEICA (real time kinematic GPS), pigtails and spray-paint on the ground. Cores were taken using a 30mm diameter soil core sampler. Trial 1 cores were cut into four sections according to depth: A – 0-30mm, B – 30mm-75mm, C- 75mm-150mm, and D- >150mm. Trial 2 cores were cut into three sections: A – 0-30mm, B – 30mm-75mm, C- 75mm-150mm. Olsen P lab results were collected for 120 of the 400 soil cores. These results were analyzed to compare the spatial variability of each depth. The results indicate that there is a significant decrease in variability from section A to section B for both trials. Section B and C for trial 1 have similar variability, whereas there is another significant drop in variability from section B to C in trial 2. Measuring samples below the top 3cm appears to effectively reduce noise, however measuring below 7.5cm for a steeply sloped paddock such as trial 2 may reduce variability too much as to no longer be representative of plant available P, and therefore misrepresenting the overall variability of soil P across a paddock or farm.

Introduction

In today's advanced technological world it is necessary to have a precise understanding of nutrient levels across a paddock or farm to inform fertilizer management decisions. This need has been constrained by the extremely time consuming and expensive nature of current soil sampling, especially on less accessible hill country farms. In recent years new technologies have led to the experimentation of the use of remote sensing technologies for mapping soil properties such as nutrient levels. One of the preliminary issues that need to be addressed in order to use these technologies is to understand the spatial variability of soil nutrient levels, as well as the variability caused by sampling methods. This is the initial study of a project which aims to determine the appropriate soil sampling depth to eliminate soil noise from cow pats and to assess spatial variability of soil Olsen P to produce a more accurate soil nutrient map compared to current methods (standard 0-7.5cm sampling depth). This research assesses a method for reducing soil noise by modifying the soil sampling depth, for use for variable rate fertilizer applications. Results indicate a positive outcome for removing the top 3cm from soil samples to significantly reduce variability of Olsen P.

Hill-country farmers are always looking for ways to maximize their on-farm production while reducing costs and increasing their profit margin. The introduction of aerial applications of fertilizer has allowed a significant increase in pasture production due to the reduction of nutrient limitations. However, using this new technology is very costly and if the fertilizer is not applied efficiently costs can outweigh the benefits as excess nutrients end up in valleys and waterways, or some areas are unnecessarily over-fertilized.

Maintaining P status is essential to encourage legume growth in pasture, and therefore nitrogen fixation. This is significant for optimizing pasture growth, especially in winter months. The ideal Olsen P value ranges from 15- 35 g/kg on most sheep and beef properties; the value is dependent on soil type, amount of dry matter grown, rainfall, slope and livestock enterprise variables. The current practices of uniform farm management (e.g. blanket applications of fertilizer) are not sustainable practices. Superphosphate, for example, should be applied until S is not a limiting factor. Sulphur (S) leaches as much as five times faster than phosphorus (P). Sulphur (S) is much cheaper than - P should be applied as one can afford (Cornforth and Sinclair, 1984). However if a farmer can afford it there are significant benefits to pasture growth of increasing P levels to aid growth of clover which will fix more nitrogen which pasture species need to maximize dry matter output. However it is necessary to determine more precisely the level of nutrients (such as phosphate) across a farm or paddock in order to variably apply fertilizer as is appropriate. This will reduce environmental impacts of excess nutrient runoff into waterways, and will ensure farmers get the most out of their fertilizer applications with minimization of cost due to more effective fertilizer applications.

Fertilizer application decisions rely on soil sampling to determine the rate of application over a farm. Soil sampling of hill country farms has always been an extremely time consuming and expensive exercise, with fairly inaccurate and unreliable results. This is due to the difficulty of obtaining precise measurements when using a sampling method of collecting a few samples across several transects and averaging the output of all samples taken from the area of concern. Research carried out at Limestone Downs, in the Waikato region by Yule, Grafton and Chok (10 December, 2013) has proven that nutrient levels in hill-country farms are very variable. Current soil sampling methods that may give an average of 23 g/kg (Roberts, 2013) P across a paddock have levels measured of anywhere from 4 g/kg P to 103 g/kg P. The need for improved levels of accuracy has led to pioneering experimentation of the use of remote sensing technologies for mapping soil nutrient levels. One of the preliminary issues that need to be addressed in order to use these technologies is to understand the spatial variability of soil nutrient levels, as well as the variability at different sampling depths. Taking samples below the current 0-75mm could reduce the impact of soil noise in the data (i.e. decrease variability) from cow pats which would improve the accuracy of current sampling methods, as data points with such data noise are misrepresentative of the surrounding area.

Materials and methods

Site selection

This project involved collecting 200 samples from each of two trial sites (Trial 1 and Trial 2) at 'Patitapu' in the Wairarapa. The sites were selected according to accessibility and slope- Trial 1 was located in a gently undulating paddock. Sample cores were taken to a depth of greater than 150mm. Trial 2 was located on a moderate to steeply sloped paddock. Cores were taken to a maximum depth of 150mm due to difficulty in consistently reaching deeper than this; especially on steeper drier parts of the slope.

Core collection protocol

200 cores were collected from a predetermined grid at each of two separate trial sites. Trial 1 was a 200m x 100m grid, and Trial 2 was a 220m x 80m grid. Grid size was determined by the shape and size of the paddocks for each site. Each grid had cores taken at intervals of 5m, 10m and 20m (See figures 5 and 6). Core sites were mapped out on a Landsat 8 image (NASA) of the Trial sites using ArcGIS 10.2 (ESRI, Redlands Ca.) prior to going into the field. This gave two sets of 200 GPS points that were then marked out using a LEICA (real time kinematic GPS) to find the points, and pigtails and spray-paint on the ground to indicate where to take the core. Cores were taken using a 30mm diameter soil core sampler. Cores were laid in a plastic half pipe, wrapped in cling film "Gladwrap", put in a plastic, labelled re-sealable bag and placed inside a poster tube to prevent loss of moisture. At the end of each day in the field all cores were stored in a cooler until scanning. Each core site was photographed, and scanned with the ASD to obtain hyperspectral data for the overlying vegetation. Moisture readings were taken in the field with a FieldScout TDR Soil Moisture Meter for trial 2 only.

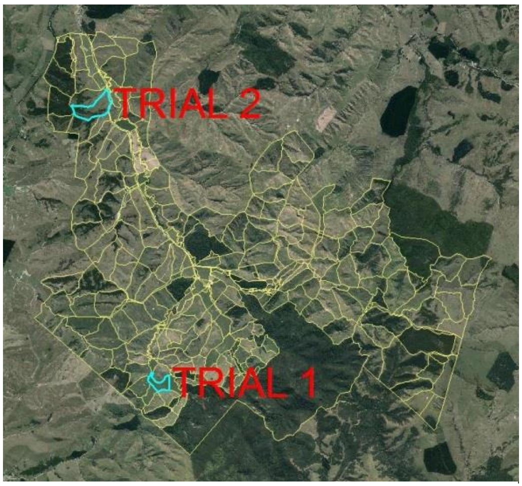

Figure 1: Trial sites at 'Patitapu' farm, near Eketahuna.

Figure 2: Eduardo marking our points with the LICA

Figure 3: Joel taking cores with the 30mm corer

Figure 4: Core being wrapped by Miles

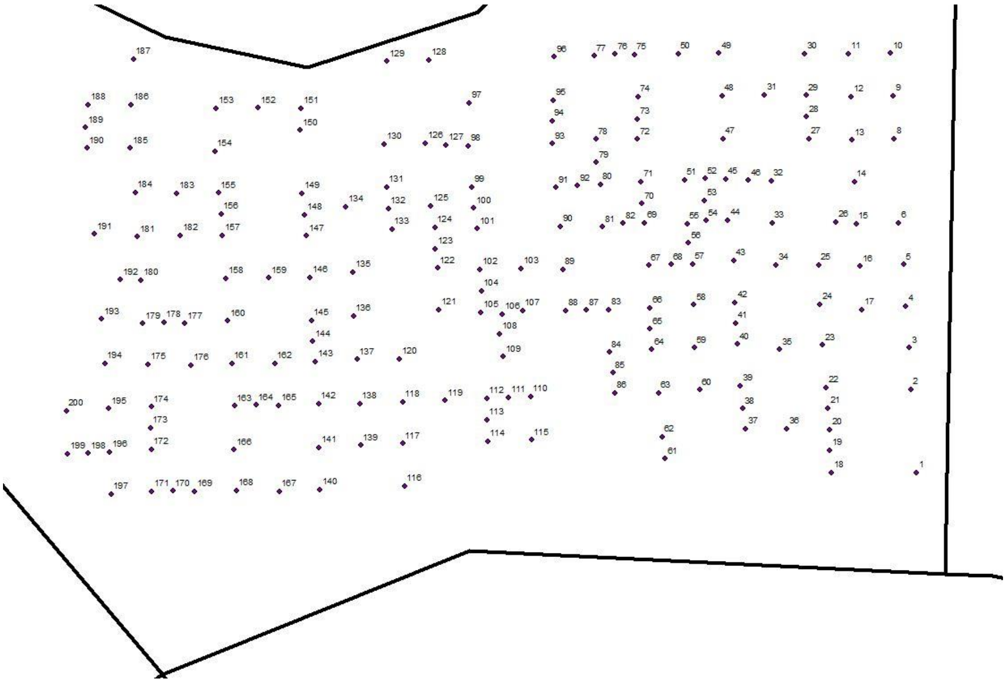

Figure 5: Trial 1 core sites

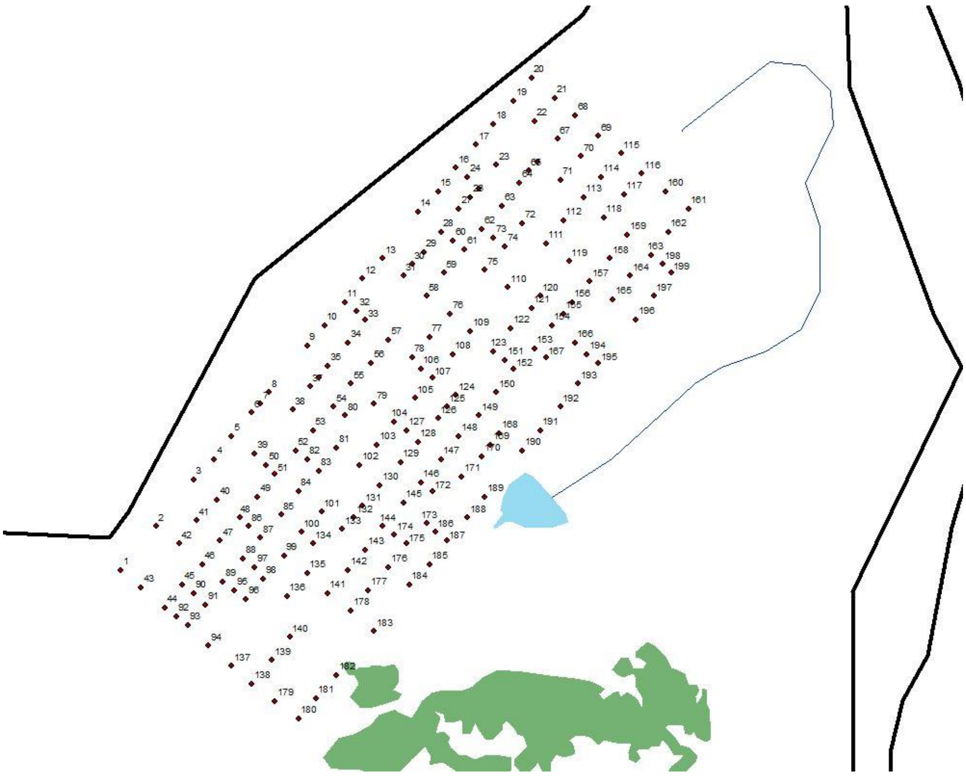

Figure 6: Trial 2 core sites

Sectioning of soil cores
Trial 1 cores were cut into four sections according to depth: A – 0-30mm, B – 30mm-75mm, C- 75mm-150mm, and D- >150mm. Trial 2 cores were cut into three sections: A – 0-30mm, B – 30mm-75mm, C- 75mm-150mm.

Each sample was ground using a pestle and mortar and sieved through a 2mm sieve. Once dried and ground each sample was scanned again using the ASD.

Measurement of soil nutrients
Soil P was determined using routine lab analysis at ARL (Ravensdown). Once cut, the 200 cores from each Trial site made a total of 800 samples for Trial 1 and 600 samples for Trial 2. This made a total data set of 1400 samples across both Trials. Of these, three lots of samples were sent to ARL to be tested for soil P. The first lot of samples was selected by random number selection, picking one randomly selected number from every ten cores (1-10, 11-20, 21-30 etc.). The second lot of samples was selected according to estimates of plant P taken from the overlying vegetative hyperspectral data. Equal numbers of high, medium and low P values were selected. The third lot of samples was selected according to spatial distribution- a set of cores from one end of the trial site.

Results and Discussion

Relationship of soil Olsen P levels at different depths
The graphs below show the relationship between each section of the cores for both Trials (see figures 7 to 11. For Trial 1, sections A and B have the strongest relationship of P levels, followed by C and D, and then B and C; whereas Trial 2 has the strongest relationship between B and C. This is possibly due to the fact that Trial 2 was on a steep slope where the top 3cm of soil (represented by section A) is subject to erosion. This downward movement of the soil means this section is not necessarily going to relate to the soil beneath it. Trial 1 was a relatively flat paddock so it is more likely there is a strong relationship between the P levels of A and B. The results of A versus B and B versus C for both trials combined obviously just produces an average of the two sets of results. The dataset is limited and can only give an indication of relative strengths of relationships between layers.

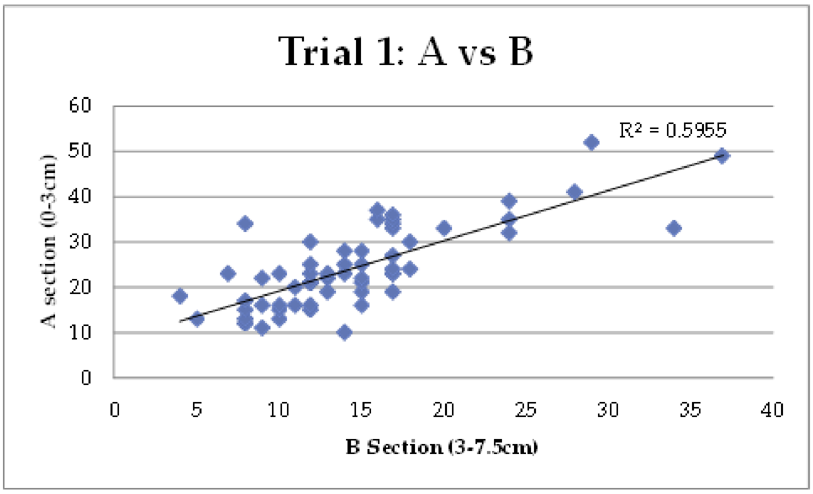

Figure 7: Comparison of soil P levels for Trial 1, section A vs B

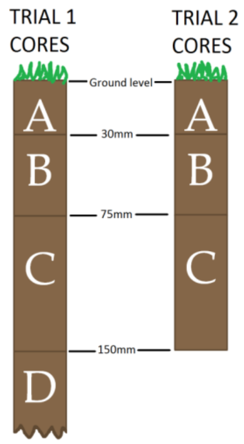

Figure 2.7: Core section depths

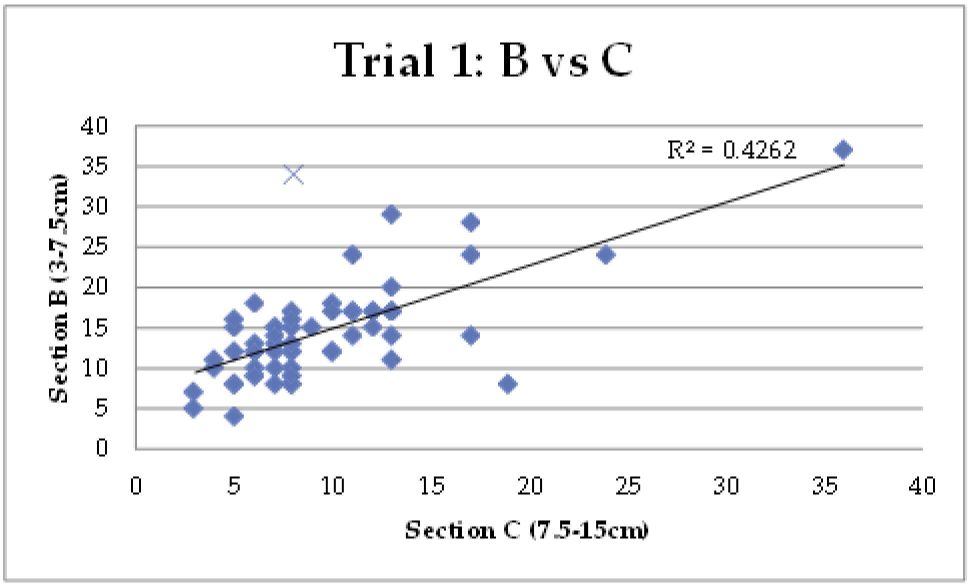

Figure 8: Comparison of soil P levels for Trial 1, section B vs C

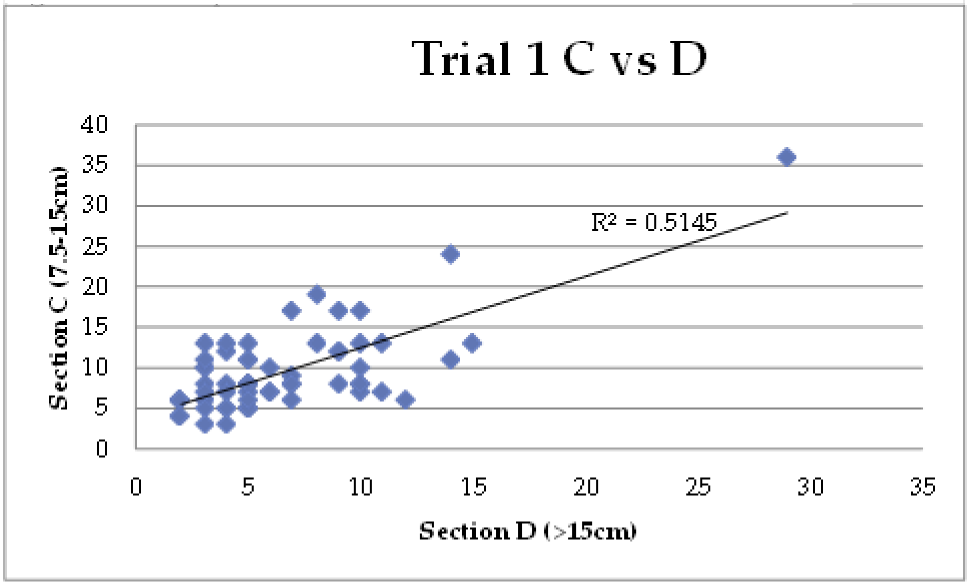

Figure 9: Comparison of soil P levels for Trial 1, section C vs D

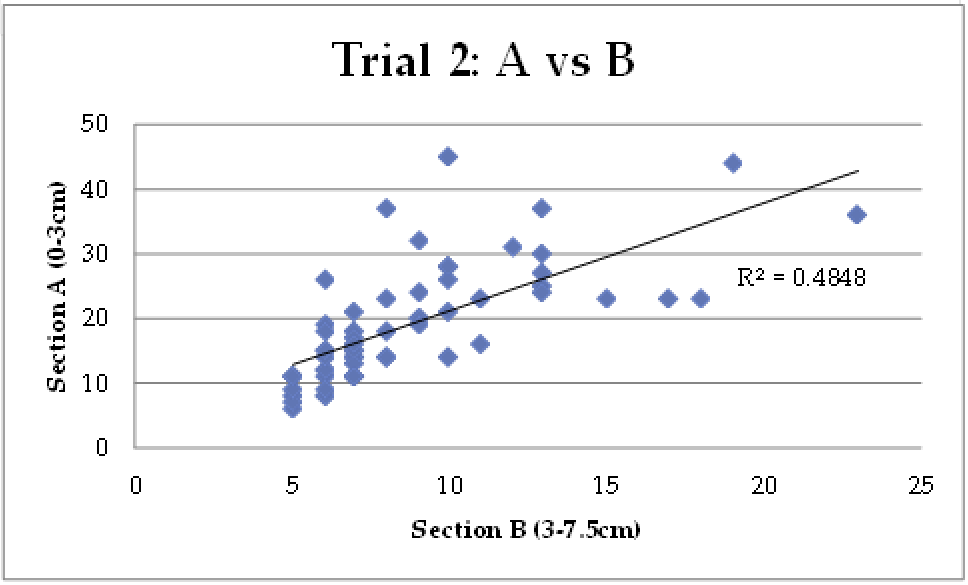

Figure 10: Comparison of soil P levels for Trial 2, section A vs B

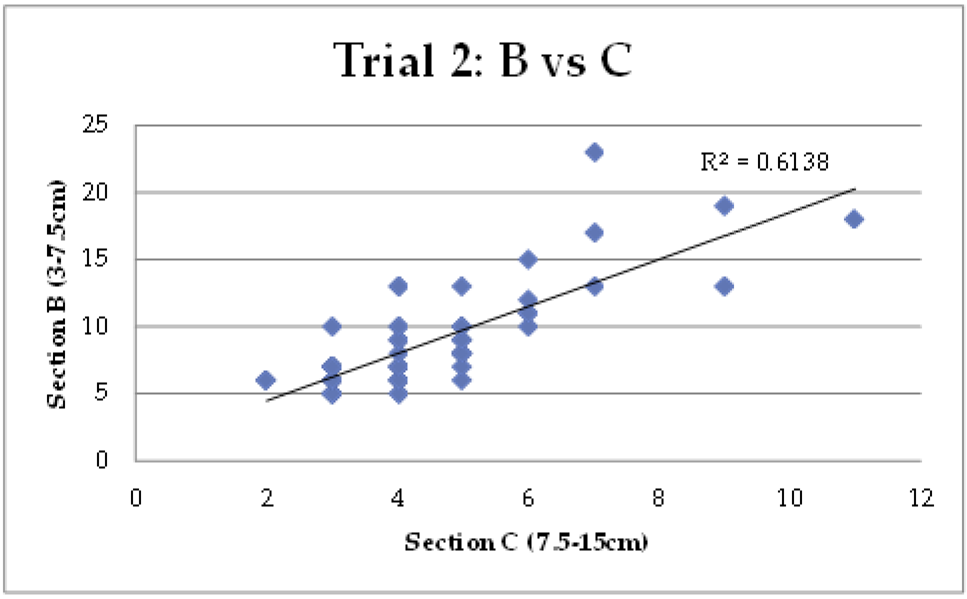

Figure 11: Comparison of soil P levels for Trial 2, section B vs C

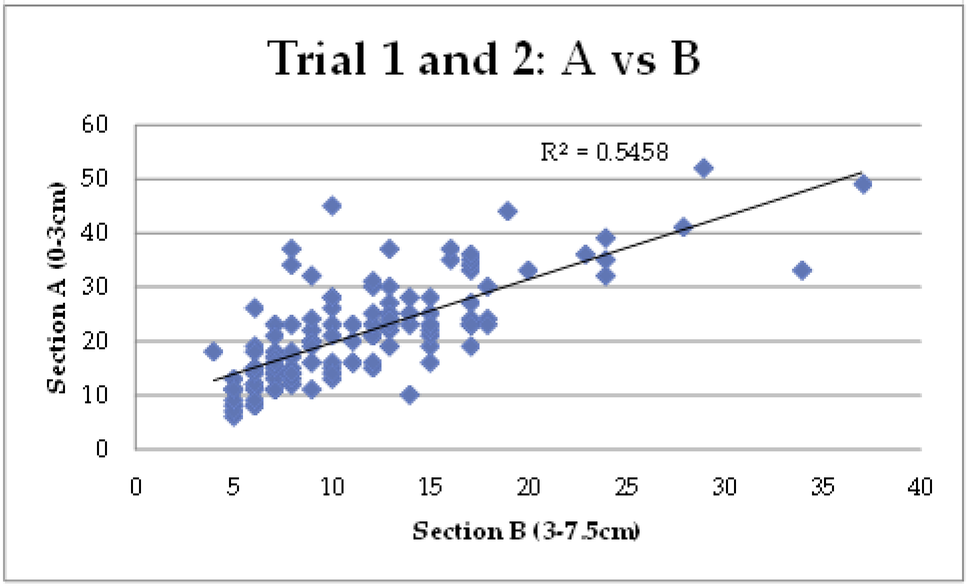

Figure 12: Comparison of soil P levels for Trial 1 and 2, section A vs B

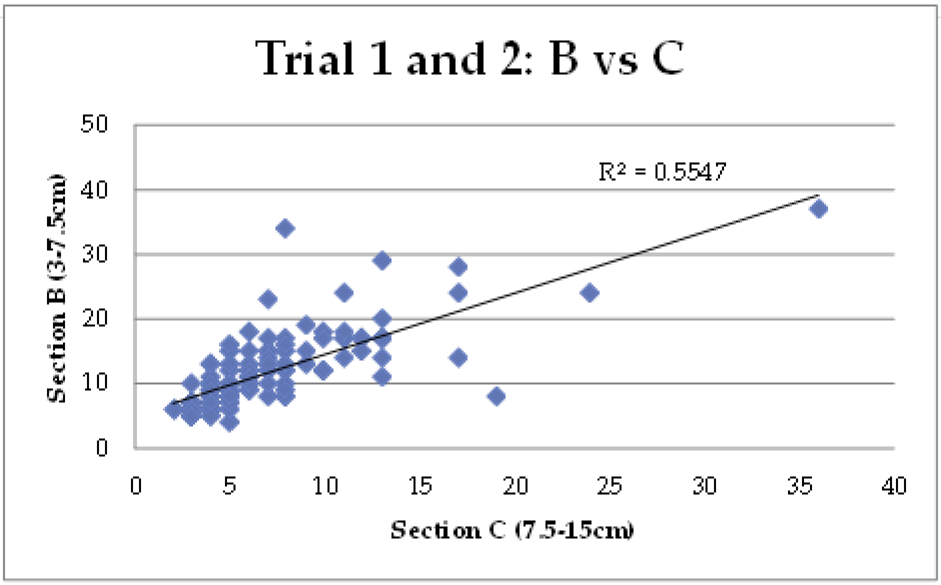

Figure 13: Comparison of soil P levels for Trial 1 and 2, section B vs C

Soil Olsen P variability with depth

The results so far indicate that there is a significant decrease in variability from section A to section B for both trials. Section B and C for trial 1 have similar variability, whereas there is another significant drop in variability from section B to C in trial 2. Measuring samples below the top 3cm appears to effectively reduce noise, however measuring below 7.5cm for a steeply sloped paddock such as trial 2 may reduce variability too much as to no longer be representative of plant available P, and therefore misrepresenting the overall variability of P across a paddock or farm.

	Section	Min	Max	Range	Average	Standard Deviation
Trial 1	A (0-3cm)	10	52	42	24.27	9.154
	B (3-7.5cm)	4	37	33	14.58	6.365
	C (7.5-15cm)	3	36	33	9.55	5.334
	D (>15cm)	2	29	27	6.6	4.375
Trial 2	A (0-3cm)	6	45	39	19.18	9.006
	B (3-7.5cm)	5	23	18	8.78	3.764
	C (7.5-15cm)	2	11	9	4.45	1.678

Table 1: Summary statistics for Trial 1 and 2 Olsen P level

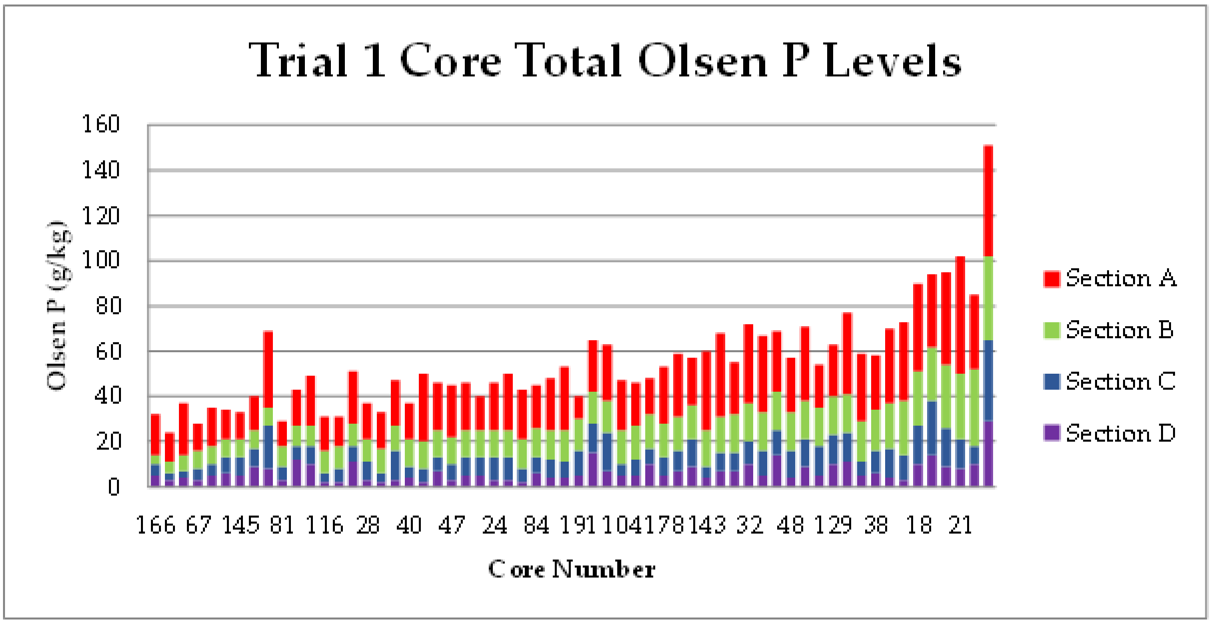

Figure 14: Trial 1 Olsen P levels for sections A to D

Figure 15 and 16 demonstrate the overall lower Olsen P values for sections A, B and C for Trial 2 (steeply sloped) as well as the greater variability of section A (seen in red) that in some cases does not correlate well with the P levels of lower sections. This is soil data "noise" that could pertain to cow pats that are no longer observable to the naked eye but can be 'seen' in the data.

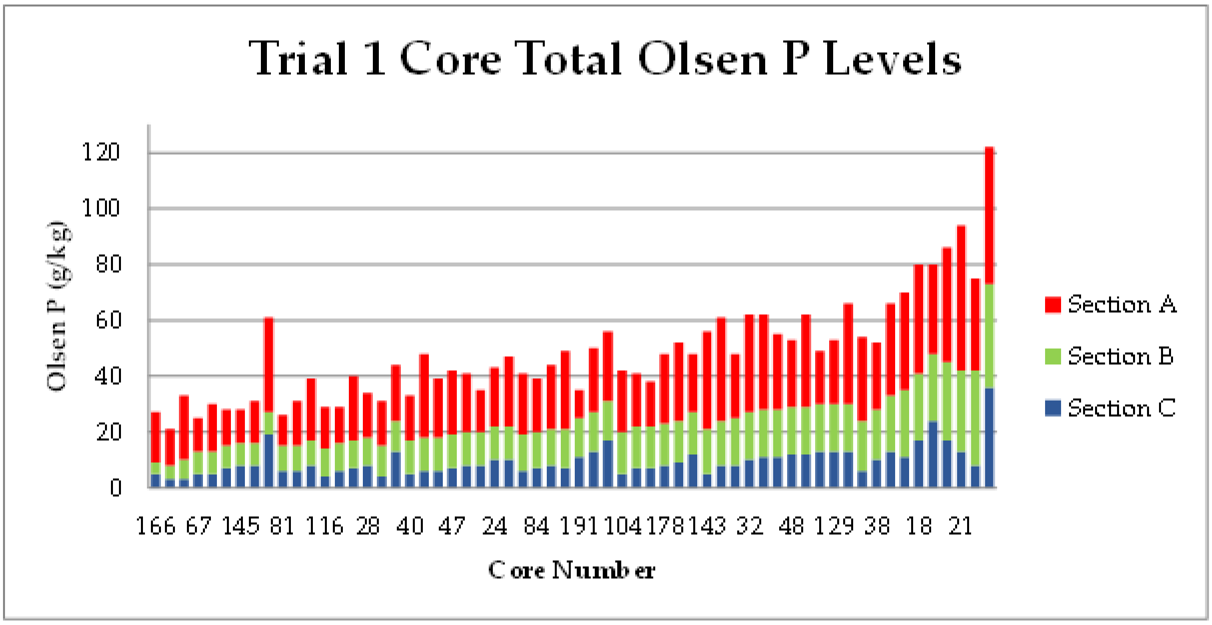

Figure 15: Trial 1 Olsen P levels sorted by Section B smallest to largest

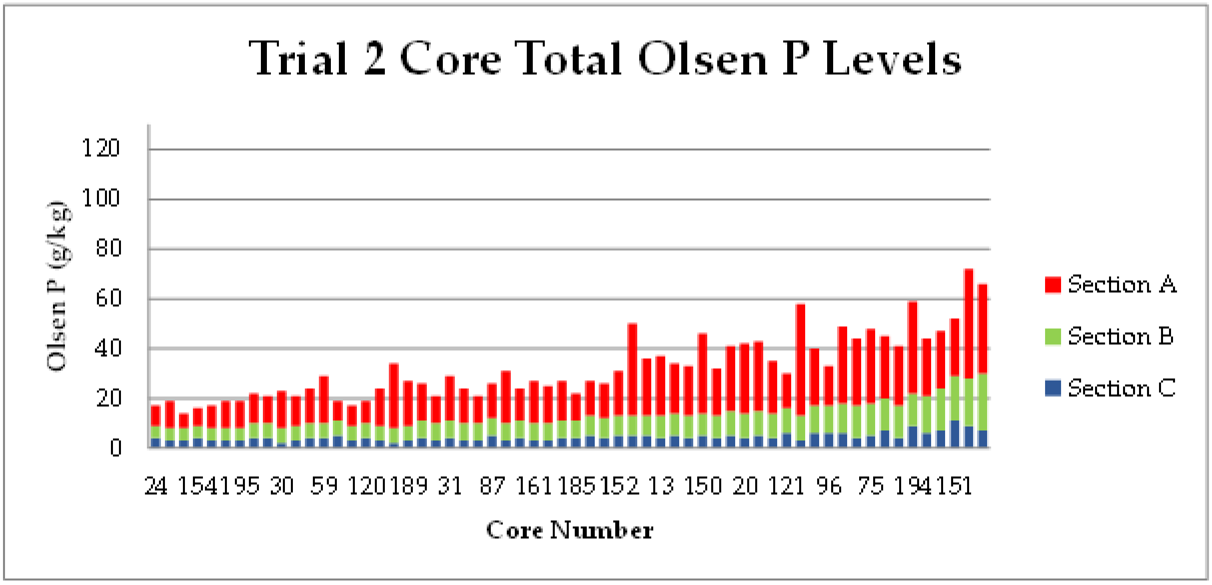

Figure 16: Trial 2 Olsen P levels sorted be Section B smallest to largest

Figure 17 and 18 compare Olsen P levels to the percentage volume of each section of sections A, B and C for both trials. It is evident that Section A with the smallest volume size mostly has the highest Olsen P, with a general decrease down the profile of each core. Section C, with the largest volume generally has the lowest level of Olsen P relative to the other layers.

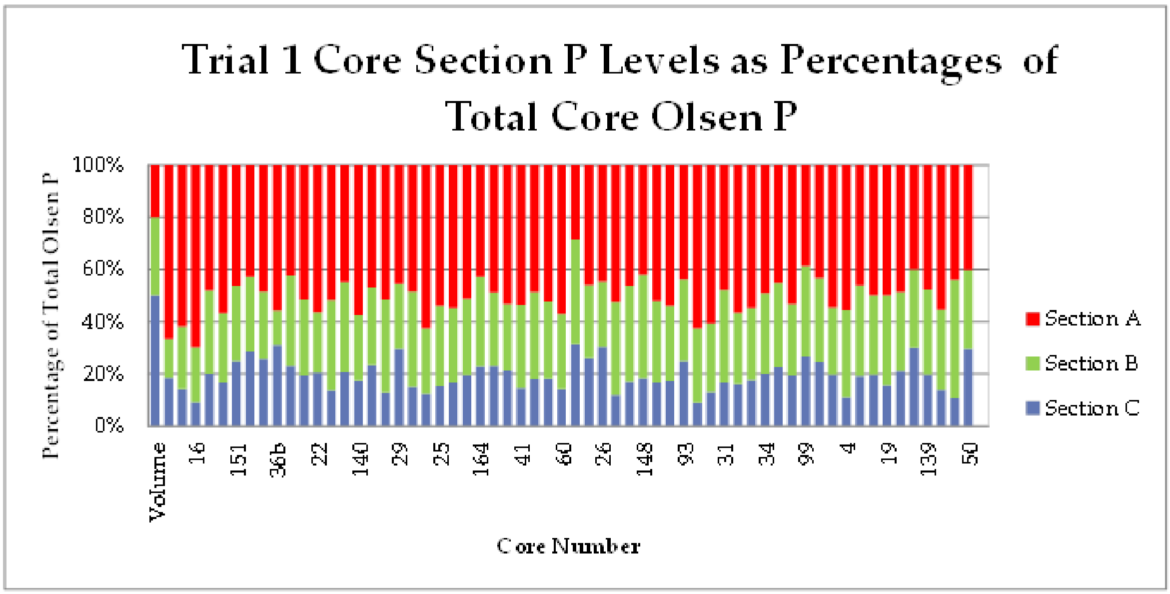

Figure 17: Comparison of each section's Olsen P level and its volume as a percentage of sections A, B and C for trial 1

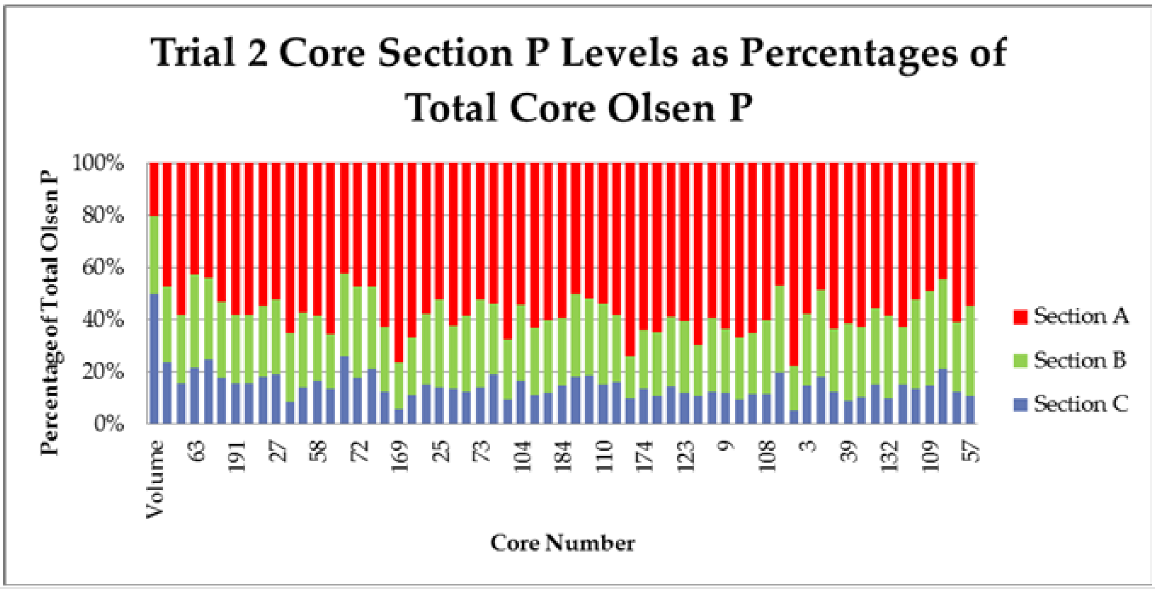

Figure 18: Comparison of each section's Olsen P level and its volume as a percentage of sections A, B and C for trial 2

Conclusions

According to literature and the results we have so far, there is definitely good potential for improving current soil sampling methods. Measuring samples below the top 3cm appears to effectively reduce noise; however measuring below 7.5cm for a steeply sloped paddock such as Trial 2 may misrepresent the overall variability of soil P across a paddock or farm. This research project will help individual farmers and the wider industry by providing improved soil sampling methods.

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Kaul TM

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