Yield Maps - More than just Pretty Pictures? Does Soil Depth Explain Spatial Variability of Yield on a Central Queensland Black Vertisol?

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ABSTRACT

Yield mapping is increasingly being adopted by central Queensland grain growers to measure the extent and magnitude of spatial yield variability within paddocks, based on the premise that *"you can't manage it, if you don't measure it"*. Often growers do not get past the initial recording process, as identifying the cause of yield variability can be time consuming and complicated. This paper presents the results of a study that investigated the impact of soil depth on the spatial variability of yield, measured with a yield monitor for a summer sorghum crop planted in December 2005. Prior to this study, soil depth and the corresponding plant available water capacity (PAWC) were anecdotally considered the leading cause of yield variability on an Open Downs soil (black vertisol) in central Queensland. Results showed the variability of crop yield was not correlated with soil depth. Importantly, identifying other parameters that may have impacted on yield variability was difficult, as these were measured at a much broader scale, which complicated analysis. From a research and adoption perspective this has important implications. If yield mapping is to be adopted and utilised effectively, tools and techniques that improve the identification of yield variability drivers are necessary. It is likely that this will require an increase in the spatial sampling of parameters, which is simple and cost effective.

Key Words: Farming systems, yield mapping, Open Downs soil, precision agriculture.

INTRODUCTION

Yield mapping is an excellent tool to assist with identifying and quantifying variability within a paddock. However, to measure the spatial extent and magnitude of yield variability is only the first step; what is more difficult is to identify the underlying causes of this variability and then develop and implement management options that maximise profitability and sustainability. In central Queensland, the adoption of yield mapping technology and the consequent implementation of alternate management options in dryland agriculture has been very low. Anecdotally, one of the foremost reasons given by growers for this low uptake is that many feel little can be done practically to manage the variability occurring within their paddocks.

One of the major land systems used for cropping in central Queensland is the Oxford land system. This system predominantly consists of basaltic clay soils. One of the soil types located within this system is as an Open Downs soil (black vertisol). A feature of this soil is the highly variable soil depth and the consequent variable PAWC. Webb & Dowling (1990) found that the position on the slope had the biggest influence on soil depth, with areas in the upper and mid-slope generally being shallower (<0.9m) than areas in the mid-lower and foot slopes. Their work also indicated that although position on the slope was influential, it was by no means an accurate predictor of effective soil depth as both shallow and deep soils had occurred at all areas within the landscape. From a farming systems perspective, variable soil depth could be driver for yield variability; however, within central Queensland few intensive sampling surveys have been undertaken to assess soil depth variability in a precision agriculture context.

In a dryland production system, especially in the northern grain belt, crop production relies heavily on stored soil moisture; hence PAWC is an important driver of production and is inextricably linked with the depth of the soil. For the Open Downs soil, a commonly held view within the central Queensland farming community was that although yield wasn't being measured spatially, anecdotal observations by growers assumed that poor performing areas in a paddock in most years was due predominantly to soil depth. Exactly how growers knew the soil was shallow and what growers define as shallow is in itself an interesting research question. Furthermore, it was believed soil depth changed so much and so randomly that very little could be done practically, unless the paddock performance was extremely poor, in which case the most appropriate land use may be to convert the whole paddock back to pasture.

This paper investigates in field variability of soil depth and assesses whether there was a relationship between soil depth and yield (as measured by a yield monitor) and whether soil depth was the leading cause of yield variability within the study area for the season.

MATERIALS AND METHODS

An on-farm trial was undertaken 40km north of Emerald in central Queensland at the property Moonggoo (S23.15763^0, E148.05545^0). The data presented is from yield mapping in 2006.

The trial area was a 77 hectare paddock with the soil being a self mulching black vertisol (Isbell, 1996). This soil is known locally as an Open Downs soil, with some typical properties shown in Table 1.

Table 1. Typical soil properties for the trial area (after Irvine 1998).

Parameter	Surface	Subsurface
pH	8.0	8.4
Exchangeable Na (%)	0.6	1.7
Electrical conductivity (mS/cm)	0.06	0.1
Clay content (%)	67	74

The PAWC (15cm intervals) for the trial site for 0-90cm soil depth are given in table 2. This data was derived using the "trickle irrigation" method (Dalgliesh and Foale. 1998).

Table 2. PAWC for the trial area (Buck and Grundy, 2004, P. 101)

Depth (cm)	PAWC (mm)	PAWC Cumulative (mm)
0-15	31.1	31.1
15-30	30.2	61.3
30-45	30.2	91.5
45-60	26.9	118.4
60-75	27.5	145.9
75-90	25.5	171.4
Total 0-90	**171.4**	

A 1m single skip sorghum crop was planted on 30/12/05 using a zero till, opportunity cropping farming system. It was double cropped following a wheat crop that was harvested 84 days prior on 7/10/2005. Grain yield, grain protein, plant available water (PAW) and soil N levels at planting and harvest were measured; and in-crop rain was recorded.

Prior to harvest 21/04/06, grain yield and moisture monitors onboard the harvester were calibrated. Following harvest, yield data was edited with the removal from the harvest log of yield points within 10m of the centre of contour banks, 27m from paddock edges and erroneous yield points lower than 750kg/ha and greater than 4500kg/ha. The yield data was then processed using ArcView GIS software. After an initial assessment, areas of greatest yield variability (both high and low yields) on the yield map were identified to be sampled for soil depth. On 17/01/07, 141 soil cores were taken throughout the paddock, with each site spatially referenced with a handheld GPS device (+/-5m accuracy). Soil depth was recorded for each core at the depth of intersection with the underlying parent material (basalt). Soil depth data was then mapped using ArcView to assess how much of the yield variability occurring within the trial area was explained by the relationship between yield and soil depth.

To assess the relationship between yield and soil depth two spatial scales were examined, using 4.5m and 27m radii around each soil core location. Yield points from the yield log occurring within these radii were averaged and plotted against the associated soil depth for that point. The 27m radius was chosen to assess whether there were broad trends associated with soil depth that were at a scale at which some form of management decision or strategy could be implemented. The 4.5m radius was used to investigate if a direct relationship between the soil depth sample point and the recorded yield could be identified at a micro scale.

Finally, the decision support tool *HOWOFTEN* was used to characterise the rainfall experienced during the fallow and in-crop for the study area from a historical perspective. The rainfall records used for the simulation were from the Capella Post Office, which is located 10km north of the trial area and has rainfall records going back to 1890.

RESULTS AND DISCUSSION

Edited yields from the harvest log clearly demonstrate that yield was highly variable across the study area. The average yield was 2.72t/ha, however, the yield ranged greatly from 750kg/ha up to 4313kg/ha, with the most frequently recorded yield (4209 log readings) ranging from 2750-3000kg/ha (Figure 1).

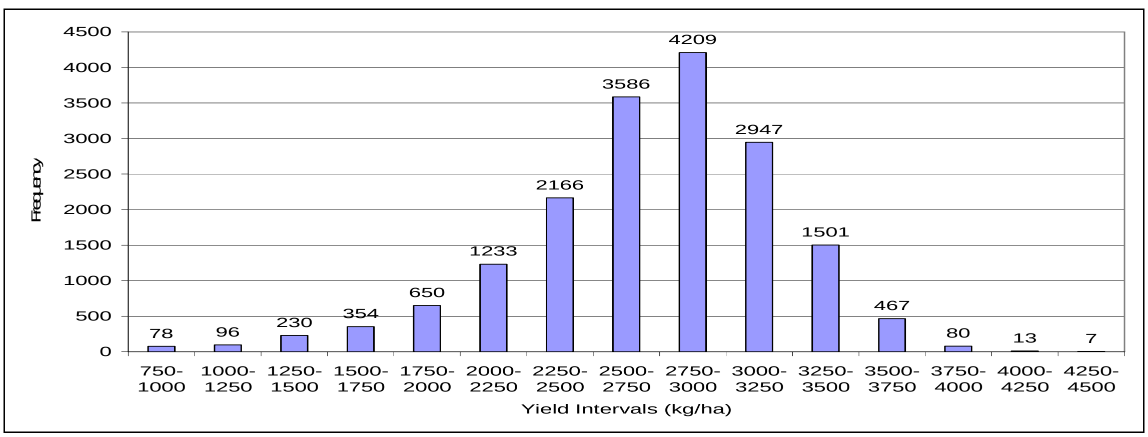

Figure1. Yield variability across the study area.

Soil depth and (it is speculated) the subsequent PAWC across the study area was highly variable as soil depth ranged from less than 45cm to over 150cm (Figure 2). The most frequently measured soil depth interval was 75-90cm (35 cores), which represents 24.8% of the sampled cores. From Table 2, the PAWC to a depth of 45cm equals 91.5mm, whilst to 90cm the PAWC equals 171.4mm, thus demonstrating that soil depth has the potential to be a cause of yield variability in this paddock and more broadly on Open Downs soils across central Queensland.

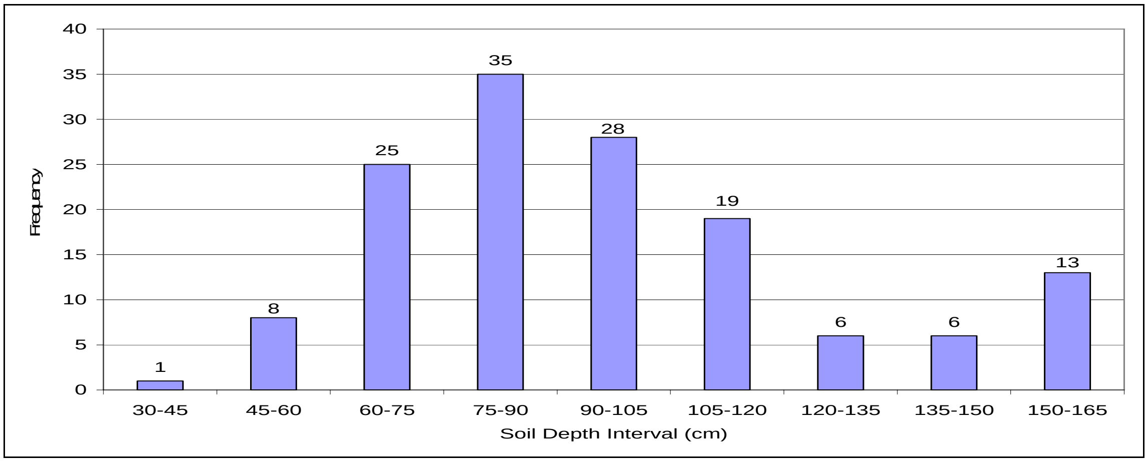

Figure 2: Soil Depth versus Soil Core Frequency per Interval Range

Figures 1 and 2 above clearly demonstrate that there is large yield and soil depth variability across the study area. However there was no significant relationship found between yield and soil depth in the study area for this season that could explain the measured yield variability (see figures 3 and 4). Neither the macro (27m radius) nor the micro (4.5m radius) spatial scale showed a strong relationship between soil depth and yield. It should be noted that yield data does have significant limitations when it comes to micro scale paddock assessment of variability, as the spatial scale of yield data is very course and thus has the potential to mask variability at a fine spatial scale.

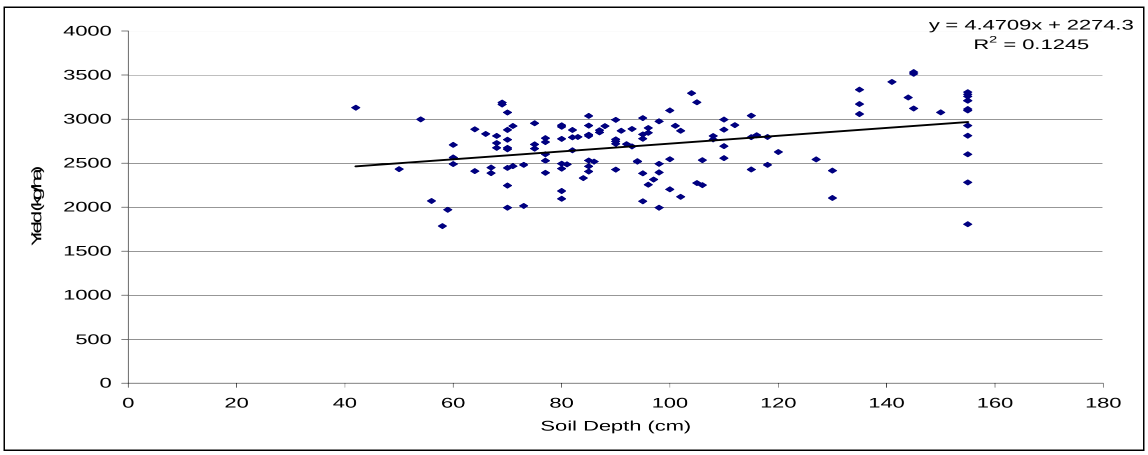

Figure 3: Average yield of yield points within a 27m radius of soil sampling points versus soil depth.

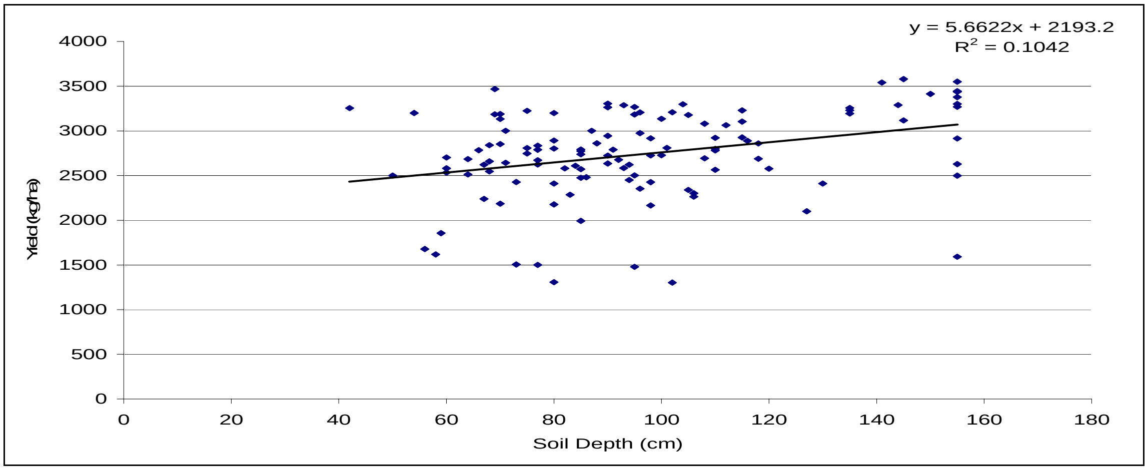

Figure 4: Average yield of yield points within a 4.5m radius of soil sampling points versus soil depth.

If soil depth is believed to be one of the biggest drivers of spatial yield variability on an Open Downs soil, why hasn't it occurred in this study? In what situations is soil depth likely to be a driver of yield variability across a paddock? The primary situation would be for example if a paddock of the same soil type had an area with 45cm soil depth and a PAWC of 91.5mm and another area with 75cm soil depth and a PAWC of 145.9mm. If fallow rainfall was sufficient to fill the soil profile to 75cm, then at planting the 75cm soil would have 54.4mm more plant available water then the 45cm area. Potentially this moisture limitation can be made up with in-crop rainfall if the season permits. Hence soil depth will most likely have the greatest impact as a driver of yield variability across a paddock when there are significant differences in soil water at planting, during seasons with low levels of in-crop rain.

The above pre-conditions for soil depth to be a driver of yield variability also need to be put in a management context. Under an opportunity cropping farming system (as practiced in the study area) cropping intensity is usually higher, planting decisions are frequently made with lower starting soil water levels and there is a greater reliance on in-crop rainfall to produce yield. Hence given the opportunity cropping management practice, the variable soil depth and corresponding PAWC of the study area are less likely to be a cause of yield variability.

So why wasn't soil depth a driver of yield variability in this case study? Rainfall during the fallow and in-crop for the study area are displayed in figure 5. Fallow rainfall equalled 359.5mm (figure includes 29.5mm of rainfall that occurred post-planting, but prior to soil sampling). A *HOWOFTEN* simulation of the fallow indicated that the amount of rainfall during the fallow ranked it in the top 14% of years. In-crop rainfall equalled 126mm. A *HOWOFTEN* simulation of in-crop rainfall indicated that the season studied ranked it in the bottom 25% of years. From this scenario it would appear that the season experienced had the potential to have yield variation as a result of soil depth.

Fallow efficiencies in central Queensland typically range between 15-20%, although they can vary greatly depending on the conditions and length of the fallow, with values being greater than 30% in some instances (Agnew and Huf, 1994). Given the previous crop was a wheat crop (harvested 84 days prior to planting) and the paddock was managed using zero till; cover levels would typically be expected to exceed 50%, which would assist with maximising infiltration in the fallow. With these pre-conditions plus the fact that the fallow ranked in the top 14% of years it was speculated that the fallow efficiency would be high, which would maximise the potential for differences in starting soil moisture due to soil depth. Soil water at planting was measured at 91mm, which was less than expected and resulted in a fallow efficiency of 15.5% (soil water at the start of the fallow was 49.3mm). This suggests that a large amount of rainfall was lost via runoff during intense rainfall events. From the PAWC values in Table 2, 91mm of stored soil water for this soil is equivalent to a fully wet profile to 45cm. As displayed in Figure 2, all but 1 of the 141 soil cores was greater than 45cm in depth suggesting that soil depth would not be a major driver of yield variability for this crop.

Another consideration is the water requirement of a sorghum crop. Based on our sampling of starting soil water, the average WUE of the sorghum crop was 12.5kg/ha/mm, which is within the range outlined by Dalgliesh and Foale (1998) for a *good* sorghum crop of 12-15kg/ha/mm (WUE = crop yield kg/ha/(in-crop rainfall + planting soil water). However in actual fact water-use efficiency varied across the study area, for example an area that yielded 1000kg/ha had a WUE of 4.6kg/ha/mm whilst an area which yielded 4000kg/ha had a WUE of 18.4kg/ha. This suggests that a factor other than soil water was driving yield variability across the study area.

If soil water was not a driver for yield variability for this crop, then what was causing the yield variability? The next logical driver is soil nutrition and in particular soil nitrogen. However measured starting soil nitrogen levels (109.7kg/ha) and sorghum grain protein levels (average 11.6%) indicate that nitrogen levels were not limiting crop production. Admittedly, soil nitrogen and grain protein levels were not captured spatially across the paddock and this highlights the fact that although yield is being intensively sampled spatially, other parameters which impact on yield like starting soil water and nitrogen levels are not. This makes identifying the causes of variability and developing and implementing appropriate management strategies inherently complex.

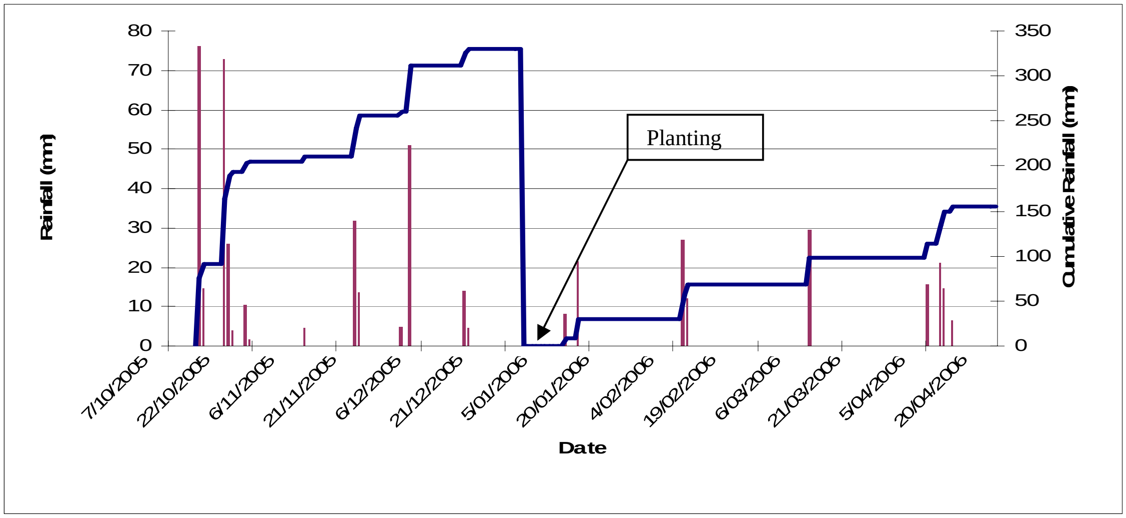

Figure 5: Cumulative and event rainfall during both the fallow and in-crop

From this study extensive yield and soil depth variability was found, however the cause of the spatial yield variability for this sorghum crop could not be identified. Although this research has not identified the cause of yield variability in this instance, it has questioned the previous assumption that soil depth and corresponding PAWC was the greatest driver of yield variability on an Open Downs soil in central Queensland. Furthermore, other parameters that may have impacted on yield variability like, starting soil water and soil nitrogen, were measured at a much broader scale than yield data, which complicated analysis and made identifying drivers of yield variability difficult. From a research and adoption perspective this has important implications. If yield mapping is to be adopted and utilised effectively, tools and techniques that improve the identification of yield variability drivers are necessary. It is likely that this will require an increase in the spatial sampling of parameters, which is simple and cost effective.

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