How Responsive is my Paddock?

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INTRODUCTION

One of the pervading questions challenging farmers when managing a paddock is; will this paddock respond to a favourable season and crop inputs? For example, a responsive paddock will produce higher yields in years of above average rainfall and poorer yields in seasons with below average rainfall. In a responsive paddock these yields would be similar to those predicted by a French-Shultz equation, where yield would increase in accordance with rainfall. In contrast, an unresponsive paddock might produce a low yield in a poor season and in an above average season produce only marginally more grain. This may be a result of an ameliorable constraint, such as a nutrient limitation or weed problem, or a more serious subsoil constraint that cannot be managed. Examples may include a strongly acid soil profile or shallow gravel close to the surface.

Unfortunately responsive and unresponsive patches are unlikely to be confined to paddock boundaries. In reality part of the paddock may be unresponsive and part may be responsive. In these situations farmers need to consider managing parts of their paddock differently, using modern precision agriculture technologies, such as yield maps and Landsat images that can be used to predict spatial variations in biomass. Traditional approaches to zone management in precision agriculture involve identifying and managing zones in a paddock that are consistently low, medium and high yielding. However, the challenge in dryland crop production is to manage inputs in a variable climate where the yield potential at a given location changes with respect to season.

We suggest the spatial variations in yield can be interpreted from a different perspective. These spatial variations imply some parts of the paddock respond favourably to the season (the above average zones) and some parts respond poorly (the below average zones). If the paddock is managed uniformly, and obvious agronomic issues, such as weeds and nutrition are already accounted for, then the spatial variations in yield give the grower an insight into how every location in the paddock responds to the season, or cropping environment.

One yield map on its own will provide growers with some insight into the spatial variation of yield, but historical studies have shown this variation may be unstable. It can fluctuate from one year to the next, causing confusion, particularly when one part of the paddock previously performed poorly, but yields well in the following year. This can occur when the seasonal distribution of rainfall is such that a subsoil constraint that limits yield, such as a shallow duplex soil that limits root growth, has no impact. Farmers may be interested in these unstable, but potentially productive components of the paddock and manage them differently from other low yielding zones in the paddock.

We therefore develop a simple method that can be applied to consecutive yield maps to determine whether a part of the paddock is responsive or unresponsive. We discuss different management options for various portions of the paddock, given the historical yield map data.

METHODS

Site description and history

Winter wheat, *Triticum aestivum* cv Calingiri was grown in 1999, 2001, 2003 and 2005 on a 190 ha paddock (116˚ 24' S and -29˚ 53' E), near Buntine in Western Australia. Lupins, *Lupinus angustifolius*, were sown in 2000. A volunteer pasture was brown manured in 2002 and canola, *Brassica napus*, was grown in 2004. Management and rainfall varied from one season to the next, but within a season, management, including the variety, time of sowing, time and amount of fertiliser and herbicide application were uniform (table 1). Soil types in the paddock ranged from a deep yellow sand, to a sandy loam and loamy clay.

Table 1. Season and management of the wheat crop in the study paddock

Year	Annual rain (mm)	May – October rain (mm)	Date of Sowing	Fertiliser N,P,K,S (kg/ha)	Seeding Rate (kg/ha)
1999	609	389	Not recorded	60,14,0,9	Not recorded
2001	283	201	19-May	65,18,0,12	90
2003	298	257	20-May	15,14,0,9	90
2005	298	245	18-May	48,12,12,5	80

Data processing

In every year, point data were logged and recorded using a commercial Case AFS yield monitor attached to a Case combine harvester. Data were post processed in ARC GIS 9.2. Data extremes (± 3 standard deviations from the mean) were removed. Yield data were interpolated onto a 25 m raster grid using global kriging to enable analyses to be carried out between years and minimise the influence of local outliers on the analysis.

Index development, yield threshold and zone creation

Three indices were calculated at every location in the paddock using four years of yield map data. These comprised the mean yield, the maximum yield and the difference between the mean and maximum yield.

We subdivide the paddock into 3 zones, poor yielding and unresponsive, acceptable yielding and unresponsive and acceptable yielding and responsive. Acceptable yield was defined by nominating a yield threshold, or yield where they are unsatisfied with the result. In this study we suggest a nominal yield of 1.6 t/ha, based on historical yield data from the paddock, but a farmer can nominate an appropriate value for their circumstances, eg a break even yield.

Poor yielding and unresponsive zones have a low mean yield and in four seasons of cropping failed to achieve the threshold yield (<1.6t/ha).
Acceptable but unresponsive zones produce, on average more than the threshold yield (>1.6 t/ha), but have a small difference between mean and maximum yield often less than 0.3 t/ha. These are consistent, economic, performing zones but unresponsive to season type.
Acceptable and responsive zones also have an acceptable mean yield, with a high difference, often approaching 1 t/ha, between the mean yield and maximum yield. In these zones, favourable seasons

often result in greatly enhanced yields. These zones are economic and, on occasion, highly productive. These zones are candidates for additional inputs in favourable seasons.

RESULTS

Whole paddock

Paddock mean wheat yields ranged from 1.89 ± 0.42 t/ha in 2003 to 2.56 ± 0.65 t/ha in 2001. 1999 was the most variable year, averaging 1.92 ± 0.73 t/ha. Wheat yield averaged 2.46 ± 0.44 t/ha in 2005. Yields from 2003 and 2005 were normally distributed, with low standard deviation. In contrast 2001 and 1999 were highly skewed, suggesting the different year 'types' generate different yield distributions (data not shown).

Spatial variation of yield

The first index, which captured the spatial variation of mean yield, ranged from 1.02 t/ha to 3.4 t/ha (Figure 1). There was a strong correlation between mean yield and maximum yield (r^2 = 0.79), but there were outliers, with many low yielding zones performing well in one of the four years. Therefore when conditions were favourable, many poor performing sites responded well. This is partially explained by the poor relationship between the difference of mean and maximum yield and mean yield (r^2 = 0.13).

The paddock was divided into the three zones, poor yielding and unresponsive, acceptable but unresponsive and acceptable and responsive. These occupied 14%, 32% and 53% of the paddock respectively. A map of the spatial variation of mean yield is presented in Figure 1. The difference between mean yield and maximum yield is presented in figure 2 and the location of the three zones is presented in Figure 3. It was noticeable that the highest yielding areas (Figure 1), weren't necessarily the most responsive (Fig.ure 3). In contrast some low yielding zones did respond and may justify higher levels of inputs in favourable seasons.

DISCUSSION

The three zones defined using the above approaches have several advantages over existing, statistically intensive approaches that farmers may have become familiar with. Firstly, the calculations can be performed easily using existing software, as complex pre-processing and data transformations are not required. These calculations could even be performed in Microsoft Excel. Thus, the biological meaning of the critical value, yield, is retained and the resultant maps can be viewed in terms of their productive capacity, rather than a transformed variable.

The difference between the mean value and the maximum value obtained at a location provide a grower with valuable information on the yield potential of the location in an ideal season. This approach treats every location as unique; the maximum yield achieved at one location might be achieved in a different season to a nearby location in the paddock. This problem has confounded the adoption of PA technologies, but we argue it does not matter what year a point in a paddock performs well, as long as it has the capacity to do so. Acceptable and responsive zones have, by definition, a large difference between mean and maximum yield and should be managed accordingly, particularly in favourable years.

The poor yielding and unresponsive zones, with a small difference between mean and maximum yield are candidates for alternative crops, revegetation or low inputs. Generally their yield can not be corrected through nutrition or weed management as they possess a yield limiting constraint that limits crop growth and yield in every season.

The outcome derived from the application of these indices is highly dependent on the threshold yield. The farmer must nominate this yield, based on their own understanding of the paddock and the yields they are satisfied with. Higher thresholds will increase the area of marginal yield and the amount of paddock classified as poor yielding and unresponsive, while lowering it will reduce the area in this zone.

Once the farmer is happy these zones mean something to them from a management perspective, variable management strategies may be employed on each of the three zones.

CONCLUSION

We have developed an index that enables farmers to zone paddocks based on the paddocks ability to respond to favourable conditions. These zones must be created with the farmer's involvement where the farmer nominates a threshold yield based on their knowledge of the paddock.

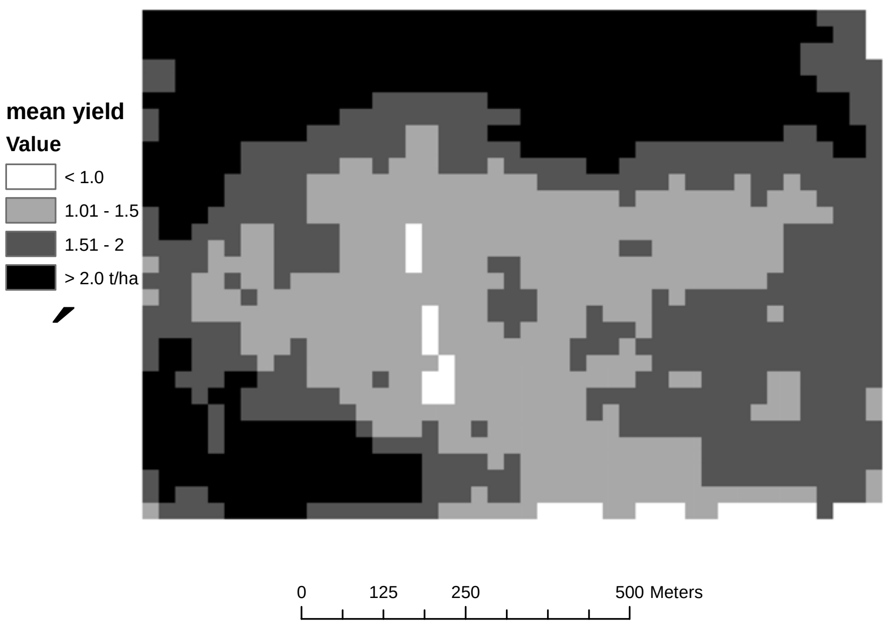

Figure 1. Mean wheat yield derived from 4 crops sown in 1999, 2001, 2003 and 2005.

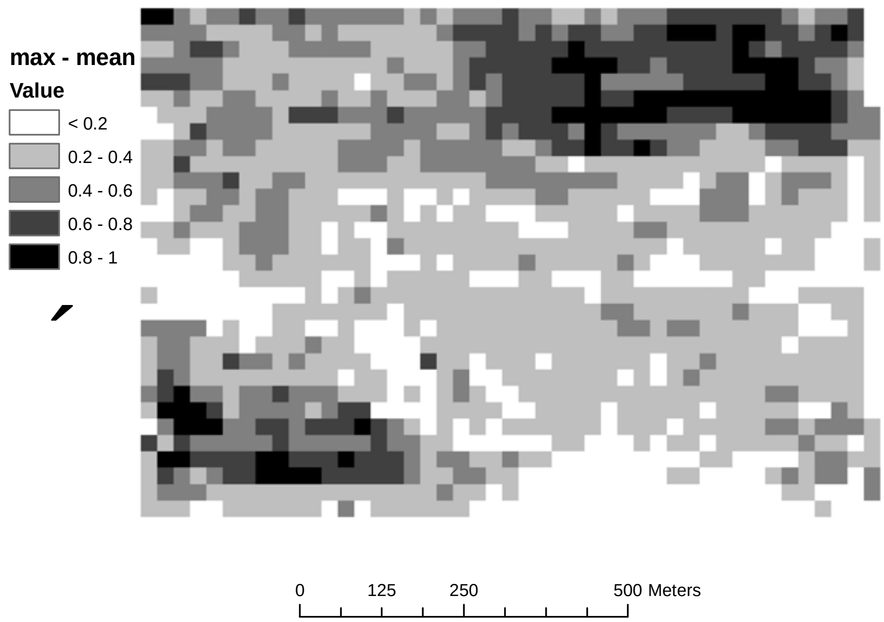

Figure 2. The difference between mean and maximum wheat yield, derived from 4 crops sown in 1999, 2001, 2003 and 2005.

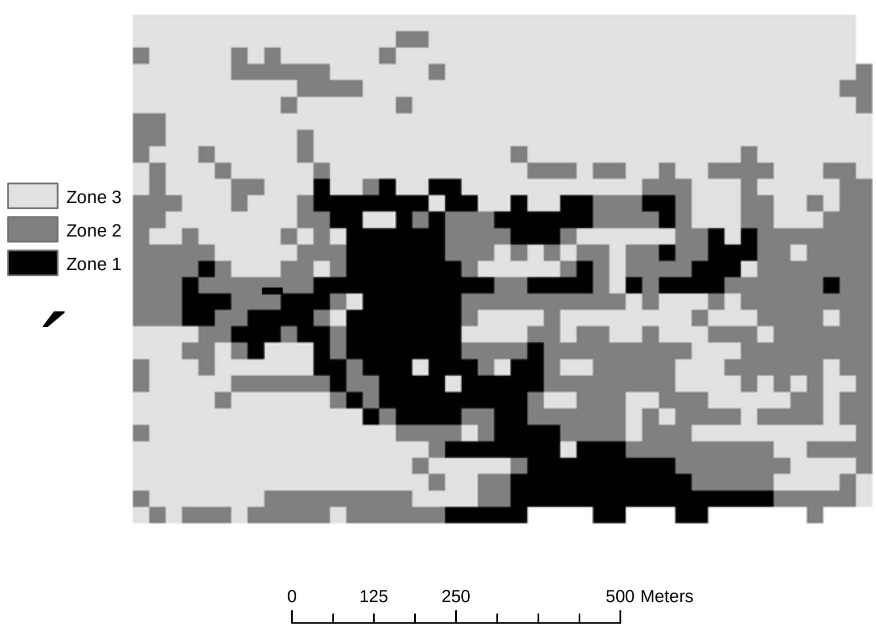

Figure 3. Three management zones, derived from 4 years of data. Zone 3 produces acceptable yields and is responsive to favourable seasons; Zone 2 produces acceptable yields but is unresponsive to favourable seasons, Zone 1 produces poor yields and is unresponsive to favourable seasons.