The case for variable rate nitrogen management

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Precision agriculture (PA) technology has brought farming and farm equipment to a whole new level of sophistication. It has heralded the development of an impressive suite of technologies including global positioning systems (GPS), picker-mounted yield monitors, variable-rate applicators, proximal soil and crop sensing systems, aerial imaging systems and a range of advanced farming software.

These tools can be applied to record information on the spatial and temporal variation within an agricultural system and more importantly can be utilised to manage this variation site-specifically. In spite of this, it is also true that precision agriculture as a concept has probably created more excitement than substantial crop improvement to the grower.

One reason may be due to the failure of scientists to clearly demonstrate the magnitude of soil and crop variation that is present in our crop production systems and fully explain the implications this variability has on profits and the long-term sustainability of the system.

One area in which PA technology has the potential to improve cotton production systems is the site-specific

28 ▷

TABLE 1: Number of random soil samples required to estimate the field average nitrogen fertiliser requirement within a specified fertiliser accuracy

	Field average nitrogen fertiliser rate			
	± 5 kg/ha	± 10 kg/ha	± 20 kg/ha	± 30 kg/ha
Field 1 (140 ha)	23	6	2	1
Field 2 (100 ha)	100	25	6	3
Field 3 (100 ha)	113	29	8	4
Field 4 (80 ha)	81	20	6	3
Field 5 (85 ha)	57	15	4	2

◁ 27…THE CASE FOR VARIABLE RATE NITROGEN

application of nitrogenous fertilisers. Most agricultural fields contain a mosaic of soil and landscape types giving uneven patterns of soil fertility and, subsequently, crop growth.

Figure 1, a satellite image of a cotton field in fallow and a picker-mounted yield map of the same field, highlights a typical example. Two significant features can be noted from these images. Firstly there is a very strong relationship between soil colour (representing different soil types) and yield patterns within the field.

Secondly, the magnitude of this variability is substantial enough to suggest that under a regime of uniform nitrogen applications, some regions of the field are being under-fertilised while other regions are being over-fertilised. Although the necessity of nitrogenous fertilisers for broadacre cotton production has been well established, questions remain as to how efficient uniform fertiliser applications are in such a spatially variable environment. To answer this question, soil samples were taken at a density of one sample per hectare from five cotton fields spread across the Gwydir and Namoi Valleys.

TABLE 2: The area of each field requiring the optimal field average fertiliser rate

	Optimal field average rate ± 5 kg/ha			
	Correctly fertilised (%)	Under fertilised (%)	Over fertilised (%)	Range
Field 1	61	21	18	–16 to +54
Field 2	65	16	19	–19 to +11
Field 3	45	24	31	–28 to +17
Field 4	45	24	29	–24 to +15
Field 5	58	20	22	–39 to +54

TABLE 3: Yield response (bales/ha) to applied fertiliser for different regions within each field

Field & zone	120 kg N/ha	150 kg N/ha	180 kg N/ha
Field 2			
Zone 1	10.33	9.26	7.40
Zone 2	9.05	8.56	7.52
Zone 3	10.85	10.55	9.85
Field 3			
Zone 1	6.31	6.43	6.40
Zone 2	6.46	6.60	6.59
Field 4			
Zone 1	7.46	8.07	8.44
Zone 2	4.59	6.01	6.92
Zone 3	4.56	5.38	5.82
Field 5			
Zone 1	7.15	7.40	7.21
Zone 2	5.81	6.50	6.81
Zone 3	5.41	5.70	5.78
Zone 4	7.44	7.57	7.64

How easily can the field average fertiliser rate be determined?

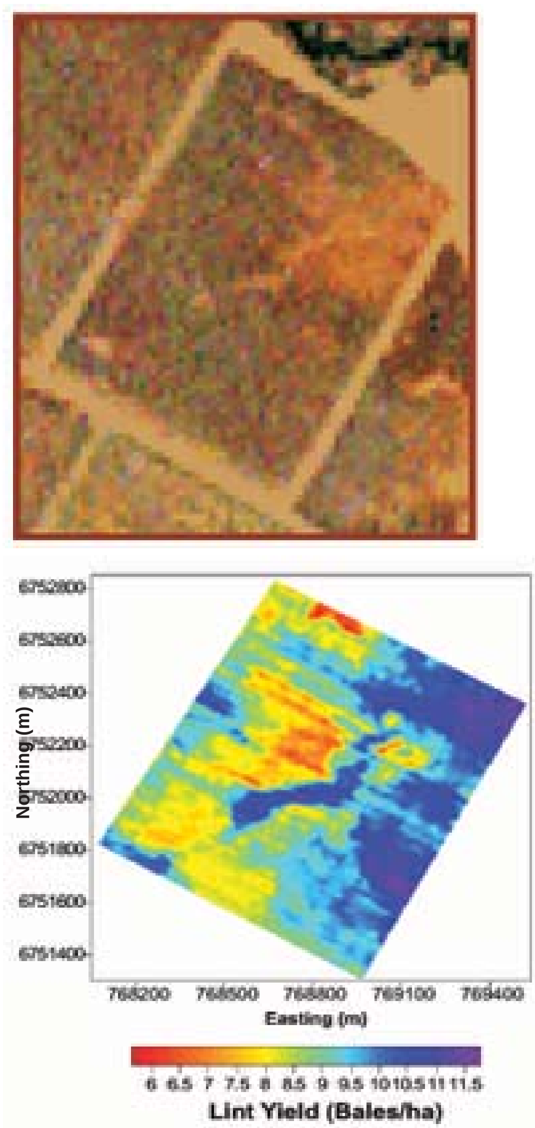
Soil sampling has generally been implemented by the cotton industry over the past several decades for nutrient testing. For nitrogen, samples are most commonly collected from the 0 to 30 cm profile depth of unfertilised soil and analysed for nitrate-N.

Current guidelines suggest taking up to 10 samples from a field, with cores of similar soil types bulked and sub-sampled to compensate for the variation in soil nitrate levels. From these sample results, most soil testing laboratories will then use some form of model to produce an estimate of the economic nitrogen fertiliser required by the entire field.

Based on the variation in the sample results for each of the five research fields, it was possible to calculate the

29 ▷

FIGURE 1: A satellite image of bare soil and a yield map from the same field



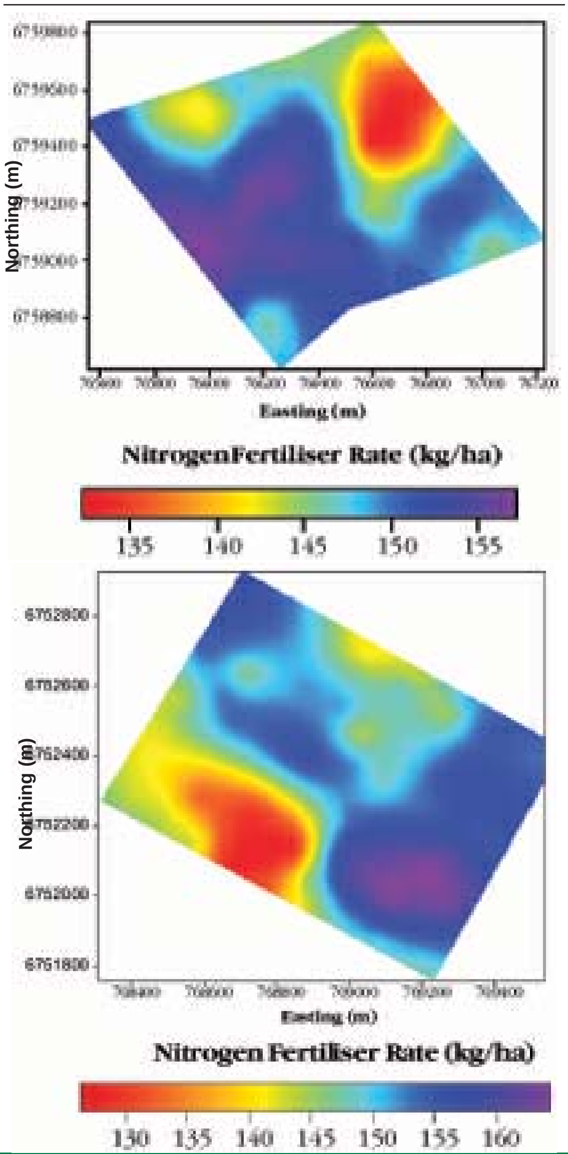
◁ 28…THE CASE FOR VARIABLE RATE NITROGEN

number of soil samples required to estimate the average nitrogen fertiliser requirement for the entire field to within a specified accuracy.

It is clear from these results (presented in Table 1) that sampling in different regions of each field could provide vastly contrasting estimates of the field average and so the amount of fertiliser required. The number of samples required to attain specified accuracies is similar between each of the fields with the exception of Field 1.

At present, soil sampling guidelines that dictate bulking up to 10 samples from each field only guarantees being within 20 kilograms per hectare of the required field rate. These results illustrate how difficult it is with a small number of samples to determine the optimum field rate given the variability that is present.

FIGURE 2: Nitrogen fertiliser requirement for Field 2 (above) and Field 4



Is the field average fertiliser rate a good representation of what is required?

A second issue associated with uniform fertiliser applications is the appropriateness of a single rate for all regions of a field. This was tested in each of the five research fields by applying spatial modelling techniques .

Figure 2 shows the spatial variation in fertiliser requirement for Fields 2 and 4. A summary of the findings from each of the fields is given in Table 2. These results found that that the optimum average fertiliser rate was only a true representation of what was required in 45–65 per cent of the fields investigated. In most cases, up to a quarter of each field is being under-fertilised and equally about a quarter of each field is being over-fertilised.

This has both economic and environmental considerations. At the extremities, some regions of each field required 50 kg per hectare less than the field average, while some regions required up to 40 kg per hectare more than the field average.

Is the crop response to fertiliser application the same in all areas of the field for a particular quantity of fertiliser?

Another implicit assumption with uniform fertiliser applications is that the crop response will be similar for the same quantity of fertiliser in all areas of each field. To test this, four of the research fields were divided into relatively homogeneous zones based on soil type and picker-mounted yield data.

Within each zone, different fertiliser rates were applied and the yield response measured. The results in Table 3 show clearly that the yield response to applied fertiliser is not uniform within any of the fields. In most of the fields, there is up to a two bale per hectare difference in yield between the highest and lowest yielding zones.

IN SUMMARY

Clearly a great opportunity exists for the cotton industry in Australia to re-examine its current practices regarding the application of nitrogenous fertilisers. These results show that uniform nitrogen applications are not very efficient. Part of the problem with current uniform fertiliser recommendations stems from the fact they are based on assumptions that there is very little spatial variation in agricultural cropping systems.

This is simply not true, so average fertiliser rates are seldom a true representation of what is required in the majority of the field. The existence of technology to effortlessly lay out variable-rate nitrogen maps presents an opportunity for growers to customise the application of agricultural inputs to their specific environment.

Further information on all aspects of Precision Agriculture and its applicability to the Australian Cotton Industry can be found in a booklet entitled "Precision Decisions for Quality Cotton: A guide to Site-Specific Cotton Crop Management" which is a University of Sydney and CRDC publication. This booklet will be available from the CRDC from June 2005.

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