Strategies to interpret the yield map: Defining yield-limiting factors

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ABSTRACT

Moisture and nutrient limitations, particularly nitrogen, commonly affect crop production in the grain-growing region of northern Australia. In this region, grain protein contents of cereal crops (wheat, barley, sorghum) are used retrospectively to distinguish, with reasonable certainty, crops to which nitrogen supply had limited grain production in that year. Using precision agriculture technologies, we collected site-specific yield and protein data of sorghum and barley paddocks during 1999. These coincidental maps were kriged onto a common grid, then interrogated, using regional trial data, to locate sites where nitrogen was yield limiting. The procedure, although at this stage still restricted to nitrogen, offers insight into the variation within a paddock on nitrogen supply, the likelihood of nitrogen limitations, and forms a management strategy for ongoing nitrogen application.

Key words

Precision agriculture, site-specific management, nitrogen, grain protein, yield-mapping.

INTRODUCTION

In the northern grain belt, supplies of moisture and nutrients, particularly nitrogen (N), frequently limit cereal crop yields. Site-specific yield monitoring provides means of locating areas where yields have been reduced but the cause, factor or factors limiting yield are unable to be specified. Until strategies are available to identify causal factors reliably, site-specific management, such as variable-rate application of fertiliser or other inputs, will be poorly matched.

We wished to test a strategy involving coincidentally monitoring grain protein as well as grain yield. Spatial variation in grain protein on a scale similar to that of grain yield has been clearly shown in studies in Europe (1), the United States (2), and to a limited extent in Australia (3). Grain protein was used in these studies to accurately determine the quantity of N removed in grain and to retrospectively determine the optimal rate of N fertiliser.

We predicted another use for spatial grain protein measurements. Using yield-protein relationships found to be robust for a variety of supplies of soil moisture and/or N, grain protein content can be used, with reasonable certainty, to identify sites where yield was limited by these factors. For example, wheat crops with a low or moderately low yield and a protein content below 11.5% have a high likelihood of being yield-limited by N deficiency. Conversely, the same low-yielding sites with protein content above 11.5% are more likely to have been limited by moisture. A similar analysis but with different critical limits can be applied to barley and sorghum crops.

Our intention was to collect coincidental grain yield and protein maps, and, by narrowing our initial focus towards N, to provide a probabilistic outcome of those sites where N supply was likely to have limited crop yield.

MATERIALS AND METHODS

Coincidental yield and protein data were collected from two paddocks near Jimbour, SE Qld, sown to sorghum and barley in 1999.

For both sites, grain yield was collected every second using an AgLeader continuous grain flow monitor. Positions were provided by an OmniSTAR differentially corrected global positioning system (DGPS).

Grain samples were collected coincidentally using an on-board sampling device. A palmtop directed sampling every 30-50 m during the harvest operation with a serial linkage to the DGPS providing site positions. The grain samples were analysed after the harvest operation for grain moisture and protein using a near infra-red (NIR) spectrophotometer.

Data layers were kriged, using Vesper (4), to a common 10-m grid using estimates of the neighbouring local variograms. The yield and protein maps were combined and queried using JMP statistical inquiry software. Yield maps were normalised to find relative responses. Nitrogen supply to the crop was estimated retrospectively from N removal in the grain (calculated from the product of grain yield and grain N content) and N transfer efficiency to the grain, derived from an inverse linear relationship between transfer efficiency and grain protein content. This relationship was derived from over 100 nutrition trials in the northern grain belt:

Nitrogen transfer efficiency = a – b . protein content (%)

where for sorghum, a = 143 and b = 9.5, and for barley a = 133.1 and b = 6.31 (W. Strong, unpublished data). The likelihood of yield being limited by N was determined from relationships between response frequency and grain protein content of non-fertilised sorghum and barley crops grown under field conditions over numerous seasons throughout the northern cereal belt (W. Strong, unpublished data).

RESULTS

Barley yield and protein content varied considerably within the 40 ha paddock (Fig. 1). Mean yield was 2.3860.59 t/ha, and mean protein was 11.061.5 %. To a large extent, variation in yield was commensurate with variation in protein; the two data sets were inversely related according to the linear model:

Protein = 16.56 – 2.31 . Yield (r^2 = 0.79*)

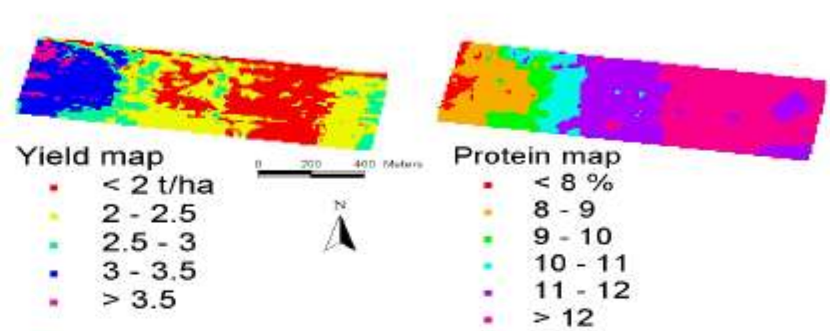

Figure 1. Yield and protein maps derived from a barley paddock near Jimbour, 1999.

Nitrogen supply varied from < 50 to over 80 kg/ha N within the barley crop (Fig. 2). In areas where N supply was consistently less than 60 kg N/ha (i.e. in the western end), the probability of N supply being limiting to grain yield was medium to very high (i.e. 60-90% chance). Grain yield in the remainder of the paddock was unlikely (i.e. 10%) to be limited by N supply for this season. Given the relatively low yields but high protein content within this area, yields were more likely to have been limited by factors other than N, such as moisture.

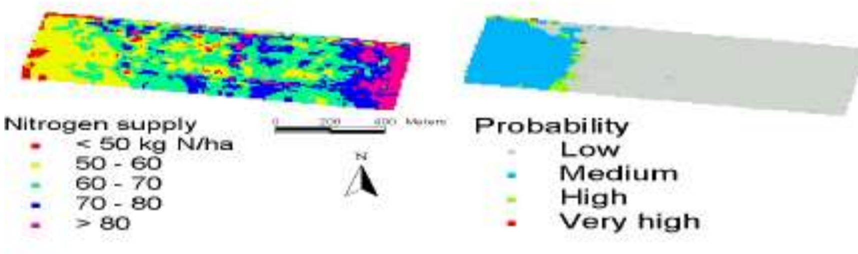

Figure 2. Nitrogen supply and the probability of N limitations derived retrospectively from a barley paddock near Jimbour, 1999.

Sorghum yield (mean of 4.7260.89 t/ha) varied to some extent within the paddock, but variation in protein content was narrow (mean of 9.6760.4 %) (Fig. 3). This limited range led to a poor correlation between grain yield and protein, as indicated by the linear model:

Protein = 10.18 – 0.11 . Yield (r^2 = 0.06*)

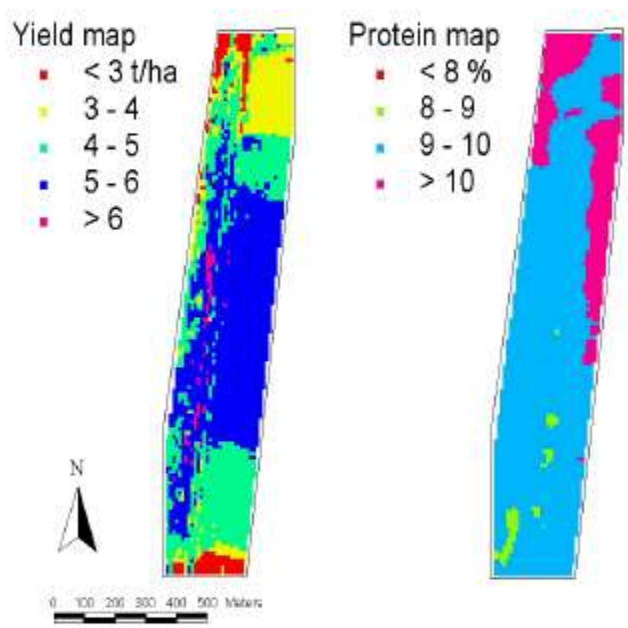

Figure 3. Yield and protein maps derived from a sorghum paddock near Jimbour, 1999.

The supply of N to the crop, estimated retrospectively, indicated the sorghum crop had large amounts of N available, much of it > 150 kg N/ha. Much of this variation was then expressed in terms of yield output rather than protein content (Fig. 4). Nitrogen supply for that part of the paddock with protein content > 9% was unlikely to be yield-limiting for the sorghum crop, as indicated in the probability map.

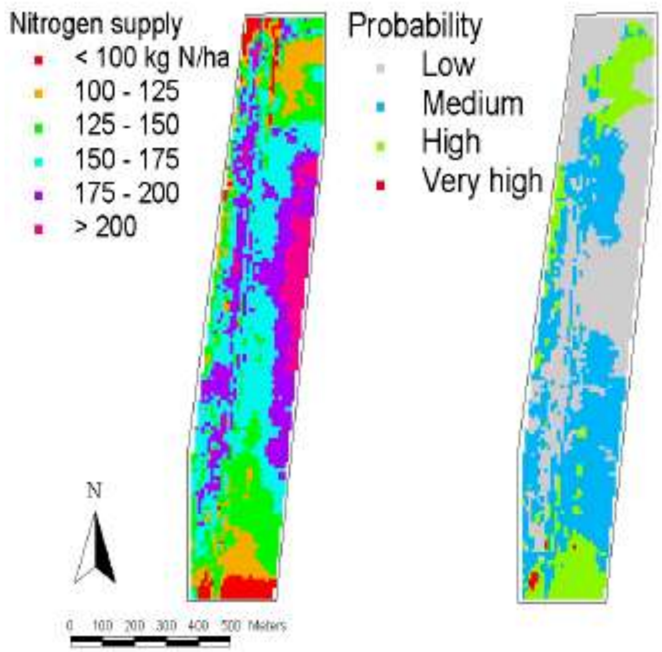

Figure 4. Nitrogen supply and the probability of N limitations derived retrospectively from a sorghum paddock near Jimbour, 1999.

DISCUSSION

The procedure presented provides a first step towards transforming the yield map from a reporting tool into a diagnostic tool. When N is in limited supply the spatial pattern of its availability to crops, particularly where limitations are indicated, could be anticipated to recur in subsequent crops due to organic matter deposition and nutrient recycling. Similarly, spatial patterns of water supply to the crop due to variations in soil texture and / or soil depth may also be expected to recur in subsequent crops. Spatial patterns of water supply due to variations in rainfall distribution and / or soil infiltration are less likely to recur in subsequent crops, and where this occurs, prediction of yield variation will eventually require environmental inputs on a spatial basis including seasonal data. Given the recurrence of factors that cause yield variation, monitoring grain yield and grain protein coincidently during grain harvest could be particularly helpful for management of N supply in both a retrospective and a predictive capacity. Site-specific grain protein values can additionally be useful for gross margin analysis that may have bearing on harvest strategy, and to assist with the segregation of grain at harvest to maximise crop returns.

In cases where management or seasonal factors (e.g. spray drift, insect damage) may create yield variation, alternative strategies must be sought to complement information where recurrent factors such as N and / or water supplies are expected to have been the prime cause for yield variation. One strategy under current investigation is the inclusion of local knowledge as an additional data layer accompanying the yield and protein maps.

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