Determining zones for yield response to N fertiliser in a paddock with subsoil limitations, using electromagnetic induction techniques

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Abstract

The inherent variability of soil characteristics leads to large variability in response to fertiliser inputs and crop yields. The variability in N response of wheat was measured along a 1500 m-long transect near Birchip, Victoria in 2001, with the aim of predicting zones for optimum N management for the entire paddock. Soil variability of the 120 ha paddock was mapped by electromagnetic induction (Geonics EM38) and the transect laid out to intercept landscape characteristics and different zones determined from the EM map. Urea was pre-drilled at 30 kg N/ha along the transect as a 10-m wide strip. Paired soil and plant samples were collected within and beside the urea strip at 50 m intervals, and crop response to N was measured at each sampling point with a plot harvester. Soil sodicity and salinity were strongly correlated with EM38 readings along the transect. On average, there was no yield response to N, but there was a positive and profitable response at 20 sample-points where EM38 values were low, and a negative response at 7 sample-points where EM38 values were high. At the other three sample-points there were large (>0.8 t/ha) yield reductions at parts of the landscape where EM38 values were high and where local topography caused run-on and high soil-N status. This localised haying-off was responsible for the lack of profitable response, on average, along the strip. The implications of these results for zone management of N-fertiliser are discussed for regions with variable subsoil limitations.

Key Words

Nitrogen, EM, subsoil constraints, crop management, paddock zones

Introduction

Where a crop has been unable to use subsoil moisture, soil sampling often reveals high levels of subsoil constraints to crop growth such as salinity, high sodicity or boron levels, often associated with high alkalinity (1). The use of EM38 maps in dryland agriculture may be an effective tool for determining zones where subsoil constraints restrict the use of soil moisture by crops. A relationship between EM38 values and the response of a wheat crop to nitrogen fertiliser shows clearly that zoned management of fertiliser application could dramatically improve overall paddock yields and profits, where subsoil constraints vary across the paddock.

Methods

An EM38 and elevation map of a paddock near Birchip, Victoria, was created in March 2001. The paddock landscape included an eastern flat, two ridges divided by a central flat, and a western flat distinguished by gilgai. A 10-m wide strip of 30 kg N/ha (as urea) was pre-drilled across the landscape variation in mid-May. The paddock was sown to wheat (cultivar H45) a month later, due to late seasonal rains.

Paired samples were taken at 50 m-intervals within and beside the urea strip. Soil samples at each sampling site were divided into 25 cm depth increments, analysed for total N (to 50 cm) Na, EC, pH and soil moisture (to 125 cm) in early August. At the same time, manual EM38 readings were made at each soil core site. Plant biomass was harvested at tillering and at harvest over the soil core sites. Grain harvests at each core site were made with a plot harvester (10 m by 1.6 m), and grain analysed for protein.

Results

The mean yield over the transect plots was 3.2 t/ha, ranging from 5.5 t/ha to 1.8 t/ha. Averaged over the length of the transect, the application of pre-drilled N in the urea strip (US) did not increase grain yield or protein. At sample sites with high EM38 readings severe yield penalties were incurred in the US samples (Figure 1). The difference in grain yield between the US and NU treatments was negatively correlated with EM38 readings (vertical, r = -0.50; horizontal, r = -0.48). Where EM38 horizontal readings >100 mS/m, and EM38 vertical readings >150 mS/m, no yield increase was seen with fertiliser application (Figure 2). High screenings, high biomass and lower grain yields resulted from haying-off at sites with high EM values.

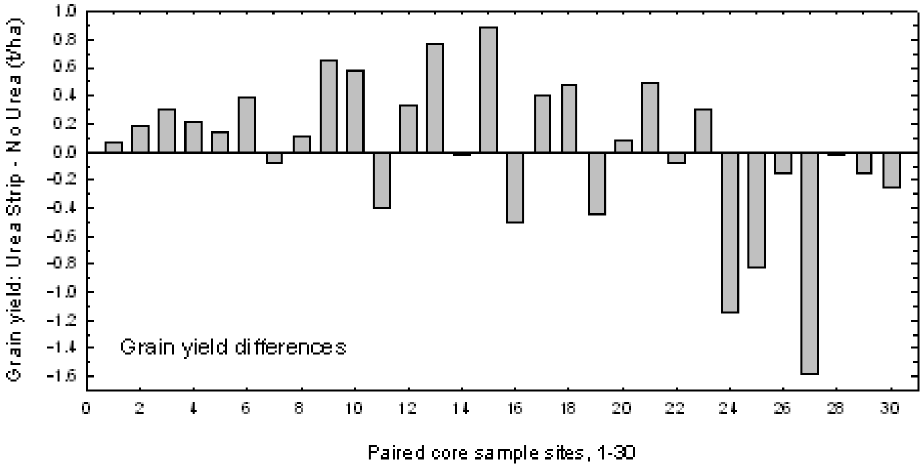

Figure 1. Grain yield differences at 30 paired sites, at 50 m intervals across a paddock, comparing an application of 30kg N/ha (Urea Strip) to no applied urea. The transect strip runs east (site 1) to west (site30).

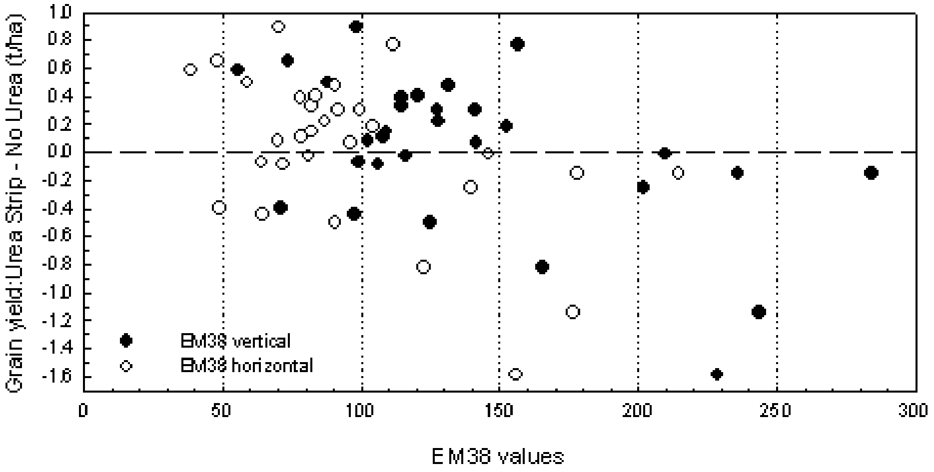

Figure 2. Grain yield differences versus EM values (mS/m). Yield was not generally improved by urea application where EM horizontal >100, or EM vertical >150 (mS/m).

Both vertical and horizontal EM readings were positively correlated with soil analyses of EC and Na (all r = 0.90, Figure 3a, 3b). Soil moisture was positively correlated with EC and Na (r = 0.62, r = 0.68, Figure 3c). Salinity, sodicity and pH all increased with soil profile depth, and more dramatically at sample sites of low elevation.

Using protein and screenings data and the Australian Wheat Board “Golden Rewards” matrix, net returns for each sample site were calculated. At the eight sites on the western gilgai flat where EM values were high, significant yield losses were incurred from applying pre-drilled urea. At 20 sample points in the transect, where EM values were low, profitable returns were obtained by the pre-drilling of urea. Most of these points were in the eastern flat and on the elevated ridges where analysis for EC and Na in soil showed low or minimal subsoil constraints due to salinity and sodicity. The best yield (5.5 t/ha) was seen on a ridge where urea was applied. Great variability in yield response was seen in the central flat, where growth was benefited by drainage from the ridges, but subsoil constraints were high, frequently resulting in haying-off. With only a small data set (n ≤60) across highly variable terrain, gaining clear correlative effects is unlikely, but some explanatory trends and possible relationships are evident.

Sampled in early August, total N in the topsoil (0.5 m) showed positive trends with EM38 readings taken at the same time, both horizontal and vertical (r = 0.34, 0.38). However, both soil moisture and N in the topsoil tended to decrease with increased elevation along the transect. As might be expected, topsoil N at tillering was positively correlated with plant biomass at tillering (r = 0.30) and with tiller density (r = 0.53). However this availability of N at tillering had negative effects on the percentage of tillers that survived to produce viable heads (r = -0.56).

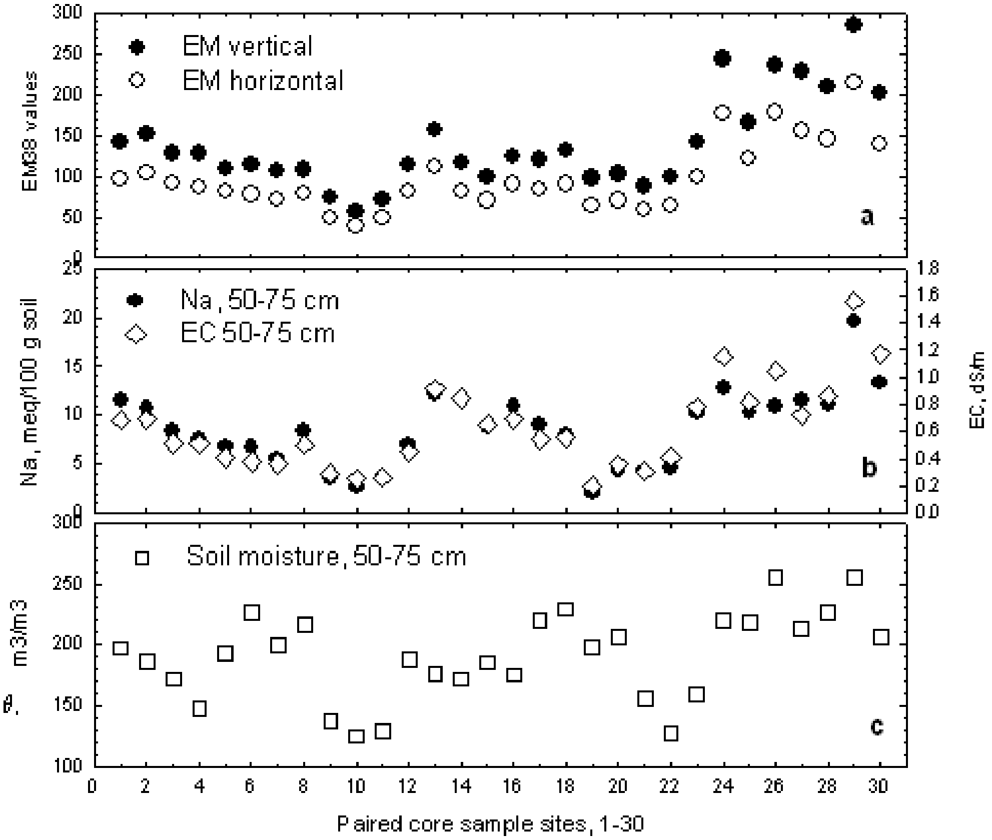

Figure 3. Mean values for (a) EM38 (mS/m), (b) Na and EC and (c) soil moisture at 30 paired sites across a paddock. The soil layer 50-75 cm was arbitrarily chosen. Horizontal EM38 readings tend to correlate with soil attributes at 75 cm.

Applying N-fertiliser as pre-drilled urea had variable success in improving crop yield when sampled over the paddock-length transect. Response to fertiliser application was dependent on landscape and subsoil attributes, which varied over the transect. Difference in grain yield (urea applied – no urea) was negatively correlated to EM38 values taken during the growing season. Application of pre-season urea to areas of the paddock where EM38 horizontal readings >100 mS/m, and EM38 vertical readings >150 mS/m would be likely to cause yield penalties, and loss of profit. It must be recognised that these EM38 readings are specific to the soil properties and conditions of soil moisture and soil chemistry of this paddock, and until tested under other conditions it cannot be assumed the values of 100 or 150 mS/m will be effective indicators of yield at other sites.

Looking at the matrix of correlations between soil properties, elevation, soil moisture and nitrogen in the topsoil, it appears that on the rising ground and ridges, where subsoil limitations were lower, both water use and nitrogen use were increased. The positive responses to nitrogen application tended to occur on the ridges and along the eastern flat where subsoil limitations were low. Despite this intuitive link between elevation and soil conditions, there was no significant correlation between elevation and salinity or sodicity, or elevation and EM38 readings. The strong correlations between salinity, sodicity and EM38 values may well be influenced by soil moisture in the subsoil. Where the chemistry of the soil solution is hostile to root growth, plants cannot scavenge water and these soils remain wet. Soil moisture has a strong effect on electromagnetic readings, and where soil moisture is not scavenged, due to hostile conditions, the effects of salinity and sodicity will not be independent from soil moisture in explaining the EM reading.

Conclusion

The use of EM38 maps in dryland agriculture may be an effective tool for determining management zones where subsoil limitations restrict the use of soil moisture by crops. Such zones may be sampled (“ground-truthed”) to determine the form of subsoil limitation to crop yield. Specific management strategies may then be formed for the future management of crops and/or amelioration of subsoil in those zones. More effective use of the data obtained in EM maps would permit better extrapolation from limited soil samples to whole paddock plans. Using EM data to create simple zones for more precise management of landscape and subsoil attributes should reduce yield penalties and thus improve overall return per paddock. Management of N-fertiliser in such zones could be one way of optimising efficient fertiliser use and profitability.

References

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