MAKING MOVIES OF ROOT GROWTH AND WATER USE--A NEW TECHNIQUE FOR PHYSIOLOGICAL STUDIES OF PLANT WATER RELATIONS
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Introduction

Capacitance probes have been a highly effective tool for irrigation scheduling in Australian cotton production for many years. Indeed a continuous trace of water use at multiple depths provides a very detailed picture of root growth, percolation and drainage. A summed graph from a single probe (Figure 1) shows daily water use on a continuous basis and allows the irrigator to effectively time irrigations when based on plant requirements. However, a single probe provides little or no information of wetting patterns further out from the probe or any indication of lateral water movement. Even when a series of probes are used to examine lateral movement, it is sometimes difficult to interpret the results from soil moisture traces. However, when the sensors from each probe are treated as points in an array and data interpolated between them in a two-dimensional plane, the wetting patterns that are created become much more pronounced. If a series of these wetting pattern ‘snapshots’ are strung together to form an animated time series, what we end up with is a movie showing the water dynamics under the soil. This technique can be highly effective for studying root growth, wetting patterns and water uptake in physiological plant studies.

The Scenario

It was suspected that a ‘wet pick’ during the 2002 cotton harvest on ‘Keytah’ near Moree, NSW caused soil compaction that may have been exacerbated during subsequent tractor operations to prepare the field for another crop. In order to determine if there were any differences in water extraction patterns caused by wheel traffic, 9 capacitance probes were installed in the 2002-03 cotton crop. They were placed in each hill and furrow moving out from the centre line of the wheel tracks (Fig. 2a) and data was collected at 15 minute intervals across the growing season. An interpolated picture was created by mirroring the probes around the centre line of the tractor and 1150 pictures showing data at two hourly intervals were spliced together to create an animation of the wetting and drying patterns across the furrows.

Wetting Patterns

Figure 2a shows the location of the wheel tracks and capacitance probes and Figures 2b – 2g illustrate the wetting patterns between the 4th and 5th irrigations. It is evident that the area under the tractor is waterlogged immediately after the irrigation, whereas the area away from the tractor remains much drier at that time. As the soil dries (Figs 2c to 2g) it is evident that the area under the tractor dries out more quickly than the surrounding areas. Figure 1g shows that the region under the tractor is actually drier leading up to the next irrigation than the outside rows. The plants grown in the two rows under the tractor were waterlogged early in the irrigation cycle and then moisture stressed later in the cycle. This effect was repeated during each irrigation interval and caused visible stunting of the plants in those rows. This is a symptom of poor soil structure due to compaction, and by viewing the animated data from across the season it is possible to gain an understanding of the effects of root growth and water extraction under these conditions. It is also possible to view the plant response to compaction over time.
Figure 2. Showing the layout of capacitance probes in the field (a) and the interpolated wetting pattern data at different times throughout the 5th irrigation cycle (b), (c), (d), (e), (f) and (g).
Validation

Whilst no direct measures of soil properties were made, the farmer observed visible differences in plant height between the plants growing in the wheel track rows (Figure 2a, rows 3-6). The plants growing in the wheel track rows were approximately 30cm shorter than those growing in the outer rows. This is also evident in the dramatic differences in plant yield observed using an on-board yield monitor (Figure 3). Given that the plough was 12 rows wide and the picker was 4 rows wide, this enabled the wheel track rows to be harvested in a separate pass. The dramatic differences in yield due to the suspected compaction are seen as “striping” in the yield map (Figure 3). These differences also correspond to the dramatic differences observed in the wetting patterns in Figure 2 where the area under the tractor went from being water logged to moisture stressed, whilst the plants growing in rows away from the tractor were not waterlogged after each irrigation event and they did not dry out as much either.

Figure 3. Yield map from the cotton field affected by compaction. The lighter coloured (yellow and red) rows show lower yield as the picker passes over the compacted rows.

Figure 1. Summed graph showing water use from plants growing in the plant line of row 5 under the tractor. The shaded area represents the 5th irrigation cycle depicted in the wetting pattern time series in Figure 2

Conclusion

This paper presents a new technique for visualising root growth, water uptake and wetting patterns over an entire season. Two-dimensional arrays of capacitance sensors can be a highly effective way of visualising wetting patterns or (when properly calibrated) measuring the differences in water extraction between different parts of the root zone. This technique can also be used to validate the wetting patterns created by different irrigation delivery systems or to measure the distribution uniformity of irrigation water at the plant level. When pictures are viewed as a time-series animation it is possible to watch roots ‘grow’ over time. This technique is also highly intuitive and can be highly effective for extension and education purposes.

This study was not designed as scientific investigation and data presented in this paper is designed to support the technique rather than to support a finding.