Measuring deep drainage and nutrient leaching under irrigated cotton

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Introduction

Electromagnetic (EM) surveys in combination with computer models, like Sodium-SaLF, and chloride mass balance models have been used to estimate deep drainage under irrigated soils with high clay content (Willis and Black 1996; Triantafilis *et. al.* 1998; Zischke and Gordon 2000). In addition to these surveys and models we can also add field lysimeters. These have been used in southeast Queensland and northwest NSW to monitor nutrients that leach below the root zone of cotton crops (Zischke and Gordon 2000). This form of evaluating nutrient leaching is accurate, however, it is also expensive and requires a lot of time to install. They are a permanent fixture in the field to be studied and cannot be readily relocated to monitor multiple locations across a field.

Ceramic cup samplers (figure 1) are an economical alternative to field lysimeters, and relatively simple to install. They also have negligible disturbance of the soil profile and allow continuous monitoring at different depths in the same profile. The ease of installation and the relatively cheap method of sampling make this an ideal method for monitoring nutrient leaching as opposed to field lysimeters.

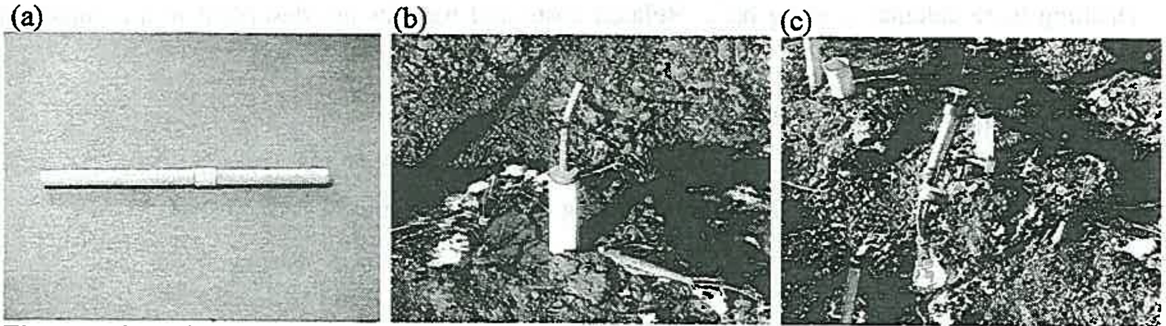

Figure 1. Ceramic cup samplers (a) used to extract soil water. The vacuum is maintained by a rubber stopper and tube sealed by a hoffman clamp (b). Soil water samples are removed by using a hand pump and 250 ml conical flask (c).

In this paper we report our experience in measuring deep drainage and nutrient and salt leaching under irrigated cotton during 2000-01.

Materials and Method

Experimental Sites and Soil Type

The three experimental sites that are being studied are at the Australian Cotton Research Institute (ACRI) (150°E, 30°S), Wee Waa (149°27'E,30°13'S) and Merah North (149°18'E, 30°11'S). The soils at each site are grey, self mulching clays. The ACRI and Wee Waa sites have similar clay contents of ~61 % and the Merah North site is sodic and has a higher clay content of 67%.

Management History of Experimental Sites

The ACRI experiment utilises a plot that had been minimum tilled (in 'permanent beds') for the past 9 years, and sown with a cotton-wheat rotation for the past five years. From 1999, the wheat stubble was not incorporated but retained as standing stubble. The Wee Waa and Merah North sites were established in 1993 and at present the Wee Waa site is sown with a cotton- N-fertilised wheat rotation with stubble incorporation. At the Merah North site the three treatments were continuous cotton, cotton-wheat and cotton-dolichos.

Determining Deep Drainage with Soil Cores

Soil cores, 1.2 metres deep were sampled at the start and end of the cotton season. They were divided into 4 depth increments: 0-0.3, 0.3-0.6, 0.6-0.9 and 0.9-1.2 metres and analysed for chloride. Drainage was then determined using a steady state chloride mass balance model (Willis 1995).

Measuring Nutrients and Salts in Irrigation and Drainage Water

Water samples were taken from the head-ditch during each irrigation at each experimental site. At each of the sampling sites a neutron probe access tube was installed to a depth of 1.2 m, and 3 ceramic cup samplers at depths 0.6, 0.9 and 1.2 m. A vacuum was placed into each sampler for a period of 7 days after which samples were removed. The soil water samples and irrigation waters were then filtered and chloride, NO_3-N, potassium, calcium, magnesium and sodium concentrations were determined. Soil water content was measured in the field with a neutron probe each time the samples were removed. Using the drainage rates determined from the chloride mass balance model and the nutrient and salt concentrations from the ceramic cup soil water samples, seasonal nutrient and salt leaching were calculated in kg ha^{-1}. Related costs and benefits are described in a companion paper (Hulugalle *et. al.* 2002).

Electromagnetic Survey

An electromagnetic induction survey was conducted using an EM38 (Geonics Ltd, Ontario) and a Magellan GPS NAV 5000 PRO™ before sowing and after the crop was harvested.

Results

Nutrients and Salts in Drainage Water

Nitrate-N and chloride measured in drainage water at the 1.2 m depth are presented in this paper (figure 2). At Merah North a high concentration of chloride was present in irrigation water between October and December. The chloride content in the soil samples removed prior to the crop being sown showed that it was also high. High rainfall and 9 irrigations during the season reduced the chloride concentration over the season by leaching it out of the root zone. The chloride concentrations in soil and drainage water at the ACRI and Wee Waa sites were relatively low, and that in drainage water remained stable over the sampling period, even though some chloride was present in irrigation water. About 1 t/ha/season of chloride was added to each plot in irrigation water. This shows that any chloride that enters the soil at these sites is leached out of the soil profile with deep drainage, and indicates that there is a steady movement of chloride down the profile.

Nitrate-N increased in drainage water sampled from 1.2 m depth with time in all three experimental sites (figure 2). This is due to leaching of nitrate-N not taken up by the crop. Values at the Wee Waa

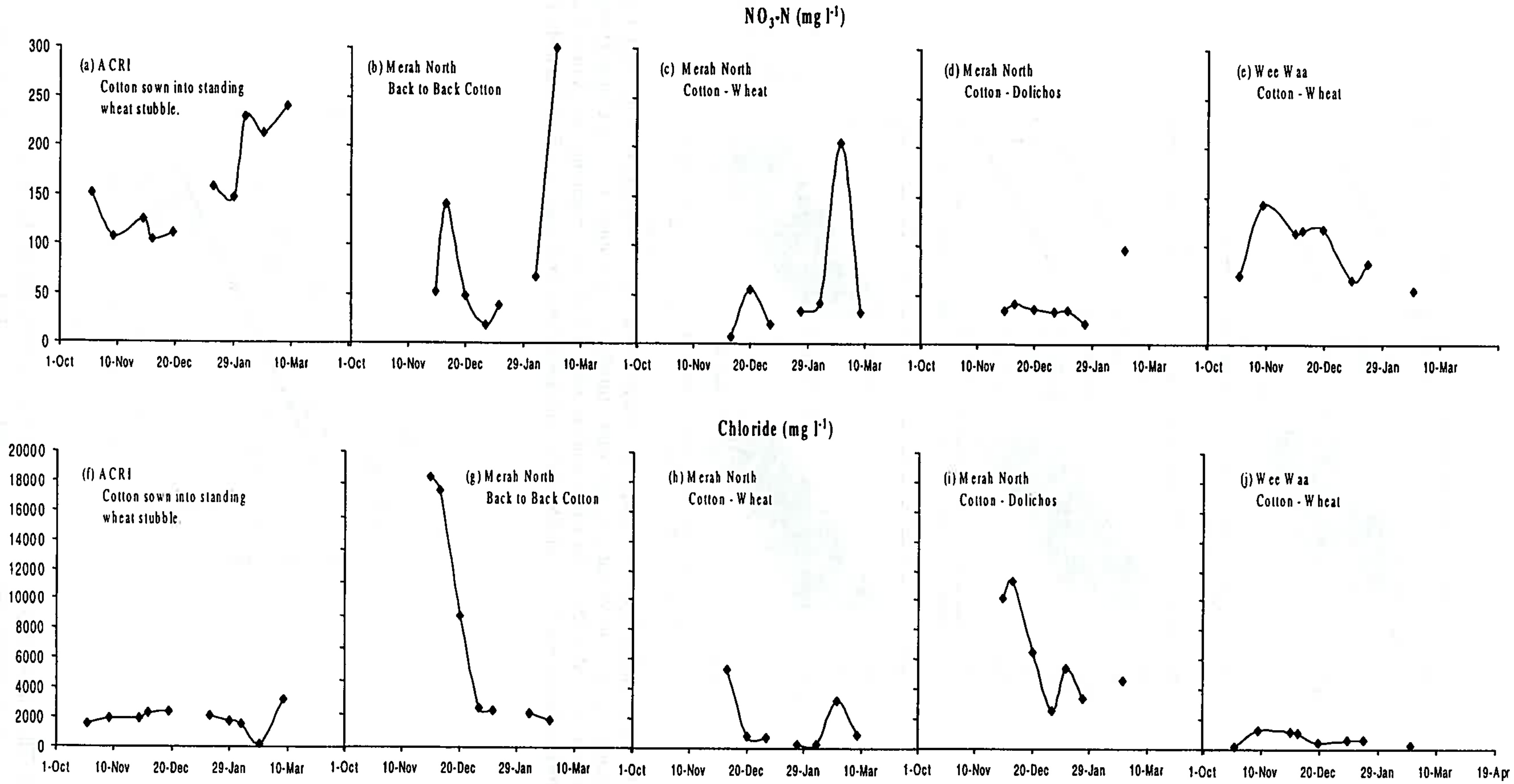

Figure 2. Nitrate-N (a, b, c, d, e) and chloride concentrations (f, g, h, i and j) in mg l^{-1} in drainage water at 1.2 m depth at each experimental site. The gaps in the graphs suggests that there is no drainage occurring.

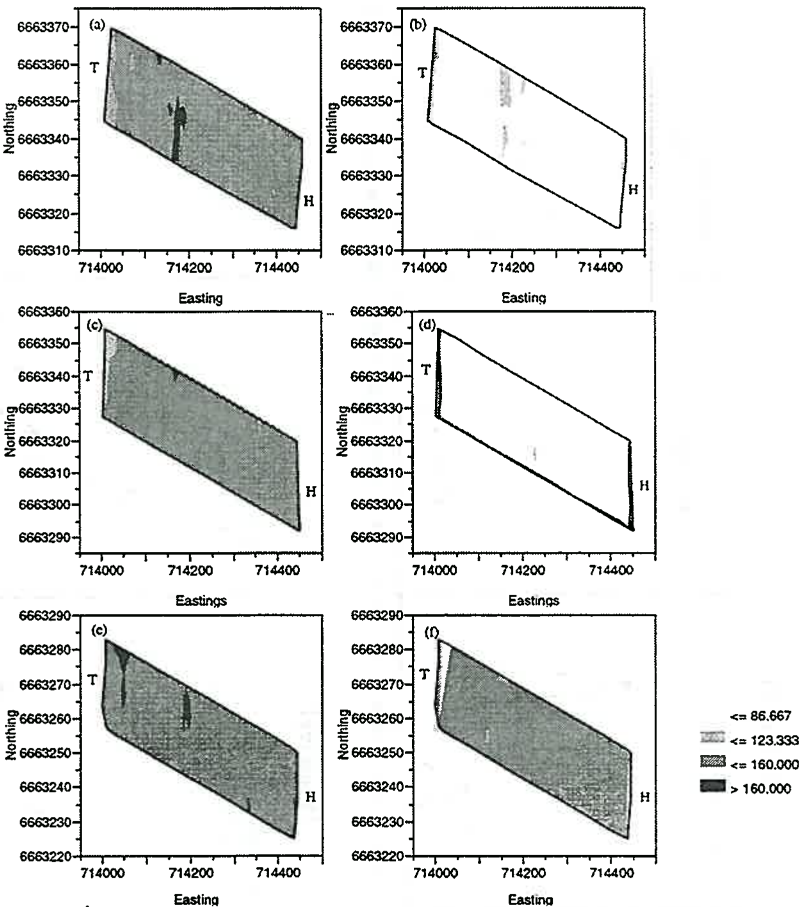

Figure 3. EM_H ($mS\ m^{-1}$) contour maps for Merah North: Nov. 2000 (a) Back to Back Cotton with stubble incorporation, (c) Cotton-Wheat rotation with stubble incorporation and (e) Cotton-Dolichos with stubble incorporation, and May 2001 (b) Cont. Cotton with stubble incorporation, (d) Cotton-Wheat rotation with stubble incorporation and (f) Cotton-Dolichos with stubble incorporation. (T = Tail-drain, H= Head-ditch).

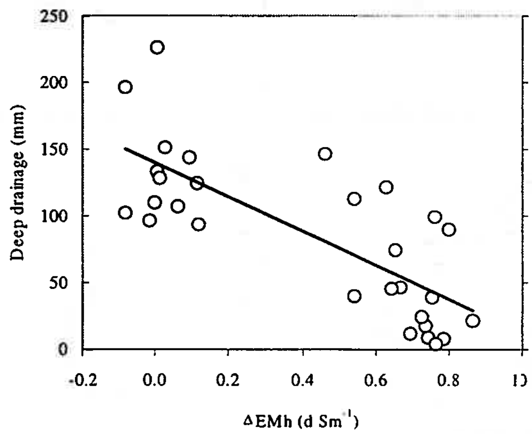

Figure 4. The relationship between deep drainage determined by the chloride mass balance model and the difference in the horizontal electromagnetic conductance (ΔEM_H) prior to sowing and after harvest. Data from all experimental sites were pooled.

site decreased later in the season, which could indicate that the roots were extracting nitrogen stored deeper in the soil. The initial increase of nitrate-N at 1.2 metres occurs during crop establishment when the plants root system is shallow. As the crop matures it begins to remove nitrate-N at depth, reducing the nitrate-N leached to 1.2 metres.

Deep Drainage and EM38 Surveys

An EM38 survey was conducted before each crop was established and after the crop was harvested. In this paper the results from the Merah North site are presented (figure 3). The Cotton-Dolichos rotation was the only treatment to show low deep drainage. The conductance of the plot also changed very little (figure 3). The survey indicated that the rotations affected deep drainage. Deep drainage estimated with the chloride mass balance model showed that it was 98, 76 and 19 mm with back to back cotton, cotton-wheat and cotton-dolichos, respectively. These values were reflected in soil conductance measured with the EM38 meter. Therefore, the EM38 conductance surveys can be used to monitor deep drainage below a crop of irrigated cotton.

A relationship between the difference between then two soil conductance surveys done before sowing and after picking cotton using the EM38 in the horizontal position and deep drainage calculated with the chloride mass balance model was derived. A statistically significant correlation between deep drainage (DD in mm) and the difference in the horizontal electromagnetic conductance (ΔEM_H) before sowing and after harvest (in mS m^{-1}) is shown below and graphically in figure 4. Data from all three experimental sites were used to derive this equation, and it will be used to estimate deep drainage in the future.

$DD = 138.76 - 126.46 \times \Delta EM_H$, $S_b = 21.46$, $n=29$, $r = -0.75^{***}$ (S_b = standard error of the slope)

Conclusions

- Ceramic cup samplers in combination with the chloride mass balance model were able to estimate the quantities of nutrients and salts that moved beyond the root zone of irrigated crops.
- A relationship exists between deep drainage determined by the chloride mass balance model and the difference in the horizontal electromagnetic conductance (ΔEM_H) measured before sowing and after harvest. This will allow deep drainage to be estimated quickly in the field.

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