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Methods for measuring deep drainage

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When cotton is irrigated a proportion of the water that infiltrates the soil moves too deep to be used by the crop. This proportion of water is commonly referred to as deep drainage and its volume and fate has become of particular interest to the Australian Cotton industry.

Excessive volumes or volumes greater than what is required to keep salts out of the root zone not only represent a lost economic opportunity but may raise the water table and the reduce the quality of ground water.

Irrigators in St George participating in the Rural Water Use Efficiency Initiative (RWUEI) recognised these potential issues and were keen to find out how much deep drainage was occurring and what methods are available to monitor it.

A trial was set up that compared four strategies for measuring deep drainage. These strategies were:

• Water balance;

• Chloride mass balance;

• Continuous soil moisture monitoring at depth; and,

• Lysimetry.

By investigating the four strategies, a cross check for the measured volume was achieved.

It is worth noting that the average annual deep drainage at this trial site was estimated prior to the commencement of this demonstration using EM surveys, soil sampling and SALF to be 21 mm

TABLE 1: Drainage (mm) past five depths in soil profile

Depth in soil profile (cm)	Drainage (mm)
Surface	840#
30	236
60	115
90	32
120	29*

This value was calculated using the water balance

* This value was estimated

The study suggests some level of deep grainage at St George.

with a range of 10 to 50 mm across the field. SALF is a computer model developed by Queensland Department of Natural Resources and Mines (NRM) to predict long term deep drainage rates based on soil properties that are easily determined.

Water balance

Water is removed from the soil by plants as they transpire and by evaporation from the soil surface. These volumes are usually combined and referred to as evapotranspiration or ET. The international standard for estimating ET known as the Modified Penman Monteith Equation was used at this site. This model calculates ET by estimating the environmental demand based on the prevailing weather conditions and making adjustments according to crop stage and vigour.

Irrigations occur when a predetermined amount of water has been removed from the soil by ET and this volume of water is referred to as the irrigation deficit. The irrigation deficit is therefore the target volume of irrigation water that is required to enter the soil in order to refill the profile. Any more is deep drainage and any less will stress the crop.

If you know how much water was supplied to the field in an irrigation event and how much water ran off as tail water then the difference is the volume that infiltrated the soil. So deep drainage can be calculated as the difference between ET and the infiltrated volume and this is known as the water balance method.

Sometimes ET can be replenished by rain. Effective rainfall is the proportion of rain water that infiltrates the soil. In this cotton season all the rain that fell was effective.

The field where the trial occurred was supplied either by irrigation or rainfall with 12.8 megalitres per hectare and of this 4.4 megalitres per hectare was collected as tail water. ET was estimated to be 7.8 megalitres per hectare. This leaves 0.6 megalitres per hectare unaccounted for. Due to the position of the meters this 0.6 megalitres per hectare includes deep drainage

TABLE 2: Deep drainage estimates beneath a cotton field at St George from a range of methods

Method	Water Balance	Chloride Mass Balance	SALF	C-Probe	Lysimeter
Drainage	<60 mm	<32 mm	21mm 10–50 mm	Some	Minimal (Preliminary)

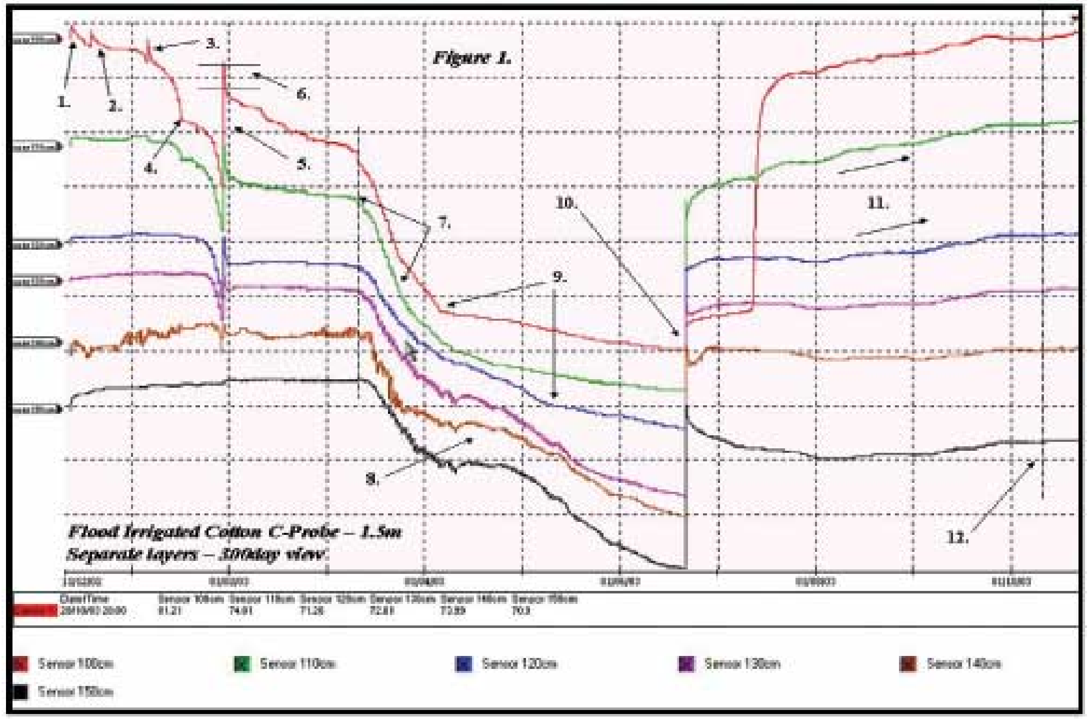

FIGURE 1: C-probe soil moisture monitoring

and evaporation and seepage losses in the head ditch and tail drain. So using the water balance method it can be concluded that deep drainage is less than 0.6 megalitres per hectare (or 60 mm).

Chloride mass balance

The chloride mass balance model uses the change in concentration of chloride in the soil profile over time to estimate deep drainage. Because chloride undergoes no chemical transformations in the soil, losses or gains of chloride from the soil profile may be assumed to be due to the movement of water containing dissolved chloride.

Changes in the total amount of chloride in the soil and the concentration of chloride in water draining from the root zone over time are used to calculate how much water (rain and/or irrigation) moved through the soil profile during a specified time period.

Soil cores were taken before and after the irrigation season and analysed for chloride. Water was sampled from the head ditch during each irrigation to measure the chloride concentration in the irrigation water.

Table 1 presents the results that were produced by the Chloride mass balance. Unfortunately, some soil was lost in the laboratory so the only information about the chloride profile at this site at the start of the cotton season was to 90 cm. As such the drainage past 120 cm can only be estimated.

The data in Table 1 indicates that 90 per cent of ET was extracted from the top 60 cm of the profile. There is a rapid drop off in drainage after 60 cm which indicates the presence of root zone limitations in this soil type. The drainage through the next two depths in the soil profile are similar. This indicates that it is likely that the soil below 90 cm is saturated throughout the season and draining.

Continuous soil moisture monitoring at depth

In cotton, soil moisture monitoring for irrigation

Sarah Hood downloading weather station data for use in evapotranspiration calculations.

scheduling commonly occurs in the top 80 cm of the soil profile. But if soil moisture was monitored at depth some conclusions can be drawn about the depth of the roots and the occurrence of drainage.

So a C-Probe was installed to record soil moisture levels at every 10 cm depth between 100 and 150 cm on a continuous basis. The following observations can be made about the graphical data displayed in Figure 1.

The graph can be divided into four periods. The first is between installation and the last crop irrigation on January 30, 2003. During this time the water content below 130 cm was gradually increasing while the water content between 100 and 120 cm was gradually decreasing. This trend continued through one rainfall event and three crop irrigations which are numbered 2 to 4 in Figure 1.

The second stage commences with the last crop irrigation where deep cracking allowed water to wet the soil to 130 cm. Some water use occurred between 100 and 110 cm from this irrigation until harvest which is shown by the vertical dash line at ‘7’.

The next two stages were a result of an effort to manipulate soil moisture contents in the interest of developing a local C-probe calibration. Firstly the cotton was left to grow and dry the soil out more thoroughly than occurs during a fully irrigated crop. From Figure 1 it can be seen that between picking and June 26, the cotton regrowth dried all depths between 100 and 150 cm.

In the last section after point ‘10’ in Figure 1, the profile was rewet by ponding the water to wet up a small plot of wheat for the C-probe calibration. The site was wet again at point 11 when soil moisture at 110 cm increased dramatically. Through this section there has been a steady increase between 100 and 140 cm and by the time of cotton pre-irrigation, all depths except 150 cm again appeared close to saturation.

The C-probe graph in Figure 1 confirms that there is an opportunity for deep drainage during the cotton season as the lower parts of the profile remain saturated. It also shows that it is possible to manipulate soil moisture contents at depth as shown by the drying of the cotton regrowth and the wetting by long inundation.

Lysimetry

A lysimeter captures the water draining over an area of soil and this water is then pumped out and measured. The pump is designed to not apply more suction than that being experienced by the soil water at that depth so that water that would not usually drain is not pumped out.

This location was not an official NRM trial site but they generously made available a lysimeter which was installed in the head ditch of this field. The top of this lysimeter was 120 cm below the average soil surface and its base was at 150 cm. Although extreme care is taken to minimise the soil disturbance associated with installation there will be a period where the soil will need to resettle around the lysimeter. So the readings last season are only preliminary.

NRM did not record any drainage during the cotton season. Throughout the cotton season there was never any water in the collection bottle until 2.5 mm was captured after the wheat was watered for two days. The C-probe indicated that the soil profile was wet to 150 cm as a result of this irrigation event.

Conclusions

Table 2 compares the methods which were used at this site to estimate deep drainage.

The water balance method estimated the highest deep drainage losses but these include evaporation and seepage losses from the head ditch and tail drain.

The chloride mass balance method and the SALF model produce similar estimates of deep drainage. The chlorine mass balance method looks promising ‘because’ it seems quite accurate and is fairly easy to implement.

The lysimeter gave the smallest estimates but it may take a season of wetting and drying to settle in properly. The C-probe did not measure the amount of deep drainage but clearly showed that deep drainage occurred when the wheat was irrigated. It also showed that there was an opportunity for drainage during the cotton season due to the saturated soil profile.

1Queensland Department of Primary Industries, St George; 2Sustainable Soils Management, Warren; 4Australian Cotton CRC, Narrabri; 3Agrilink, St George.