NATIONAL PROGRAM FOR **Sustainable Irrigation**

Research Bulletin

Measuring the effects of improving water use efficiency on root zone salinity

by Tapas Biswas, Gerrit Schrale & David Dore

Background

Irrigated horticulture in the Lower Murray (Riverland-Sunraysia) region has improved water use efficiency (WUE) over the past two decades from about 50% to about 80% as a result of improved irrigation practices. The one negative consequence of this achievement is an emerging risk of salinity build-up in the root zone, threatening the sustainability of the region. The rate of irrigation must account for both the crop's needs and an additional amount of water (the leaching fraction) used to flush salt out of the root zone. For example, when the average river water salinity is about 0.4 dS/m, a 15% leaching fraction (15% more than the crop needs) should give root zone salinity around 0.6 dS/m. However field surveys indicate that the root zone salinity, though very variable, is often greater than 1.3 dS/m.

Since the end of 2003 a tri-state syndicate of government agencies from western NSW, Victoria and South Australia has been working on a strategy to manage this salinity hazard. This Research Bulletin draws on some of the findings to date, focusing on results of monitoring root zone salinity and deep drainage in sprinkler and drip-irrigated citrus orchards and vineyards.

Measuring root zone salinity

Electrical conductivity (EC) of soil was measured at 14 Lower Murray properties during the 2003/04 irrigation season. The seasonal depth of water applied for the citrus crops ranged from 588 to 1646 mm; the associated total rainfall ranged from 235-284 mm. The vines had seasonal irrigation depths ranging from 440 to 1133 mm and total rainfall from 153 to 303 mm.

This survey indicates that the leaching of salt is poor - due not entirely to less leaching fraction but due to a 65% "leaching efficiency". Leaching efficiency is the efficiency with which the drainage water mixes with the soil solution and is accepted as100% when every mm of water passing below the root zone carries its full quota of salt.

At 4 representative sites an EM38 survey was undertaken, which uses electromagnetic resonance imaging to map the paddocks into units of greater or lesser salinity (Figure 1). The results showed great variation between core samples and between farms, but generally salinity increased with depth (Figure 2). This is expected because evaporation and absorption by the plant roots reduces the amount of free water and therefore concentrates the salt in the substrata.

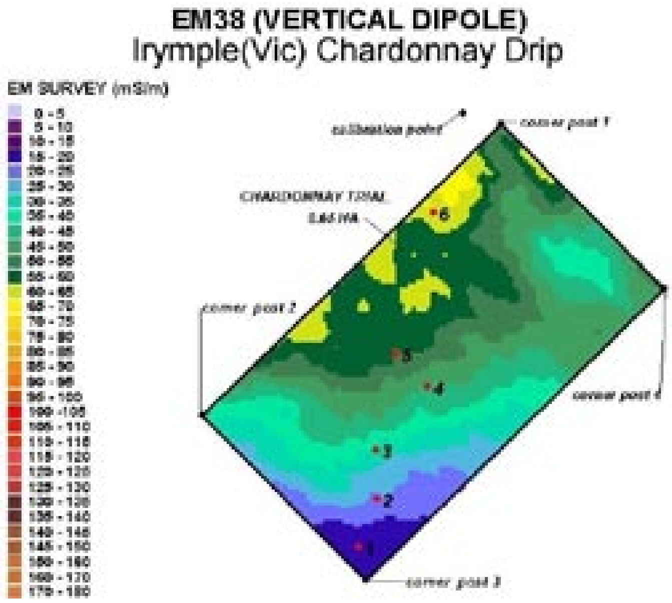


Figure 1. Map of apparent salinity (ECa) at one sample site, and location of core samples. The colours show the variability in salinity across the paddock, ranging from 0.2 to 0.75 dS/m. 1 mS/m = 0.01 dS/m. This is the map for a drip irrigated Chardonnay block.

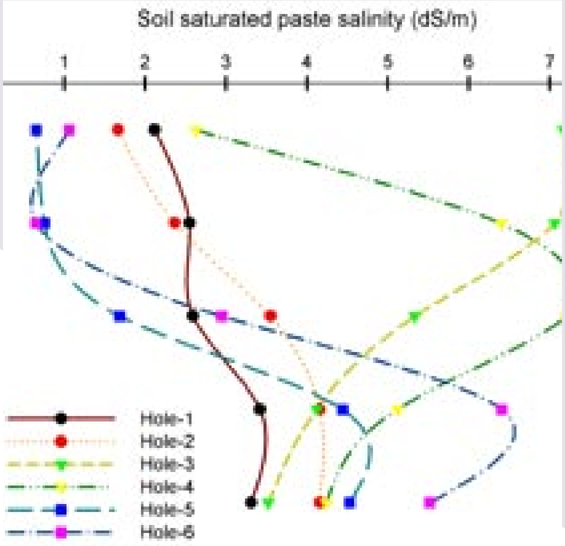


Figure 2. Variation in salinity (x axis dS/m) with soil depth (y axis in m) for each of the core samples in Fig 1

The salinity or electrical conductivity of soil water (ECsw) peaked at 20 dS/m at 90 cm root zone depth under drip irrigated vineyard, but was rarely more than 1.5 dS/m in an undercover sprinkler citrus orchard (Figure 3).

Measuring deep drainage

Four methods were used to try to determine the amount of water draining from the root zone.

These were:

1. a calculation of seasonal water balance using soil water trace;
2. simple chloride trace;
3. water balance and capacitance probe method;
4. capacitance probe method using Darcy equation.

Method 1 involves the calculation of soil water storage from soil texture, irrigation records, crop types, climatic data and crop coefficients. Excess water applied is attributed to deep drainage.

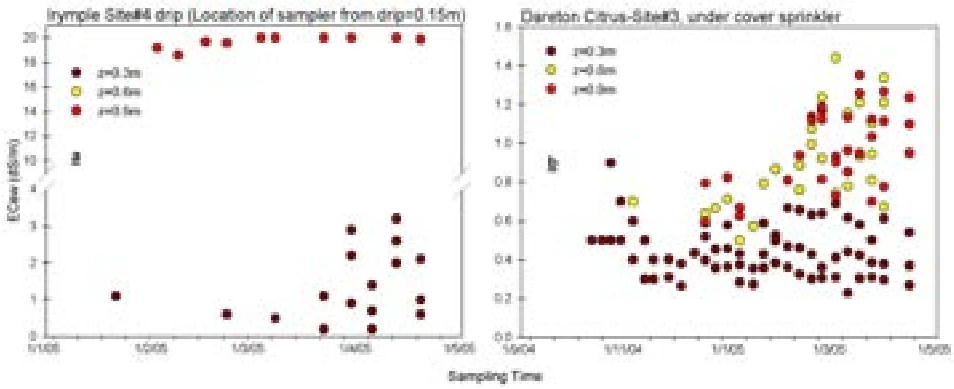
Method 2 assumes that the ratio of deep drainage to the amount of water applied is equivalent to the ratio of the chloride (Cl) concentration in irrigation water to the Cl concentration Cl in drainage water. By monitoring these concentrations in the field, a seasonal picture of deep drainage can be built up. If a Soil Solution Extractor is used, soil water can be extracted from the root zone at a standard suction pressure equivalent to that applied by the plant roots.

Method 3 uses capacitance probe logs for measuring total root zone water content, estimates of the field capacity of the soil, and rainfall and irrigation data to determine deep drainage. Where Method 1 uses crop coefficients to predict the crop's average water use at various stages of development, Method 3 makes no such assumptions, but simply derives the amount of water leaving the profile.

Method 4 uses the Darcy function to smooth hourly capacitance probe data into daily total soil profile water contents. Using these results with soil hydraulic functions the deep drainage can be estimated.

Using Method 1, it is estimated that 4 -10% deep drainage is occurring under drip irrigated vines and citrus compared to 24% and 35% respectively

Figure 3. Electrical conductivity of soil water (ECsw) under a drip irrigated vine and an under-cover (uc) sprinkler citrus tree.



for citrus and grapes irrigated by undercover sprinkler. This means that the WUE under drip is 90-95% with consequently high risk of long-term salt accumulation in the root zone and associated yield losses.

Using Method 2, drip irrigation didn't produce any leachate from the root zone at one site, and produced only 1% of applied water in another. With undercover sprinklers the estimates were 21 ± 3 % and 17 ± 4 % of deep drainage. The results are summarised in Table 1.

Table 1. Estimated Deep Drainage (Sep 04-Apr 05) from soil Cl tracing technique (Method 2).

Site	Irrigation (mm)	Rainfall (mm)	Deep Drainage (%)
Loxton vine drip	510	177	ND[a]
Irymple vine drip	343	116	1 (±0.02; n=10)[b]
Loxton vine uc sprinkler	735	177	21 (±3; n=53)
Dareton citrus uc sprinkler	912	102	17 (±4; n=31)

[a] ND=Not detected. [b] value in parenthesis indicates standard deviation (SD) and n= sample size

Using Method 3 estimates of deep drainage ranged from 7-16% and 13-17% for drip irrigation and for undercover sprinkler irrigation respectively. The results are presented in Table 2. This confirms the method 1 result that the WUE under precision drip is often more than 90%.

Using Method 4, drainage estimates resulted in negligible deep drainage (1%), which confirms the Method 2 findings.

Table 2. Deep Drainage estimated from field capacity and real time capacitance probe data (Method 3).

Site	Period	Apparent Field Capacity*	Deep Drainage (%)
Loxton vine drip	10 Dec 04-23 Jun 05	31	7
Irymple vine drip	22 Dec 04-23 Jun 05	30	16
Loxton vine uc sprinkler	6 Jan -23 Jun 05	20	13
Dareton citrus uc sprinkler	30 Jan-1 Aug 05	19	17

** based on noncalibrated enviroscan data*

What do the results mean?

Although the results from the 4 methods vary considerably, they suggest that negligible leaching is occurring under drip irrigation compared to the uniform uc sprinkler irrigation, regardless of the crops grown. Consequently, the general concern for precision drip irrigation is that if winter rainfall does not effectively displace the residual salt from the root zone, salt accumulation in the root zone is going to be a major concern.

To develop a strategy for root zone salinity management, a two dimensional solute transport model (LEACHM-TRANSMIT) simulation was run for 278 days to estimate the salt accumulation in the root zone for irrigation salinities of 0.3 dS/m (current river water salinity at Loxton) and 0.8 dS/m (the Morgan benchmark). The scenarios are shown in Figure 4. Under the scenario of drip irrigation with less than 10% root zone drainage and 0.3 dS/m, about 130 kg/ha of salt should

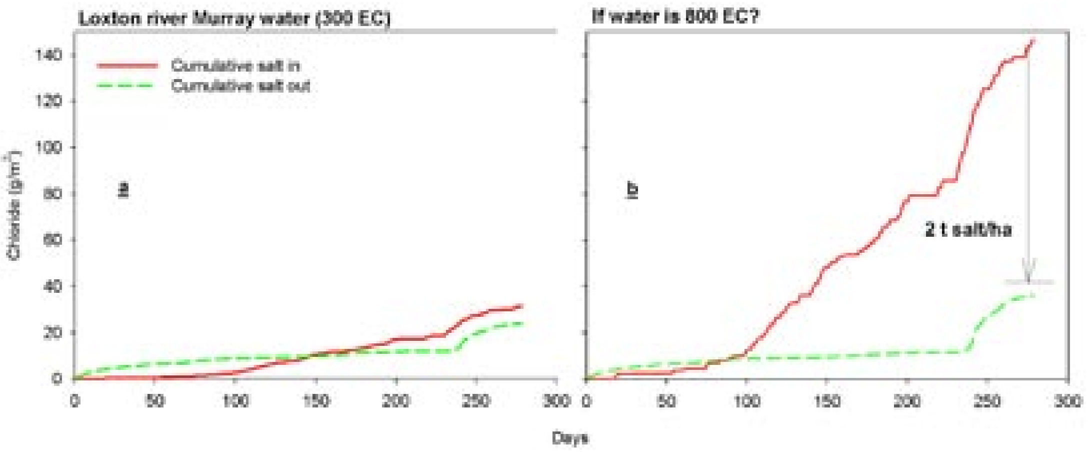


Figure 4. Results of a LEACHM-TRANSMIT simulation that predicts salt build up in the root zone with two different salinities of River water, the 300 EC (current level), and 800 EC the Morgan benchmark.

accumulate in the root zone during first irrigation season. Under the 0.8 dS/m scenario, 2000 kg/ha of salt would accumulate in a 1m root zone during a normal grape growing season.

It is important to note that the fruit and leaf analysis for the 0.3 dS/m scenario showed no significant salt problem for either grapes or citrus except at one site.

What's next?

With more field data and calibration of capacitance probes, the team plans to pin down the variations in deep drainage estimates

Tapas Biswas (left), from SARDI with Graeme Sanderson (middle) from NSWDPI and Jahangir Alam (right) from SA Rural Solution whilst installing solution extractors (top right) for monitoring salt leaching in a citrus grove at Dareton, NSW

that the different methods have shown. The detailed monitoring of daily and hourly changes in unsaturated hydraulic conductivity is proving critical to the estimation of deep drainage, as wetting periods are not homogeneous events. However the results to date suggest that deep drainage may have been over-estimated by the traditional water balance methods (Methods 1 and 3).

The team plans to measure leaching efficiency and model the scenarios of different levels of River Murray salinities on root zone salinity accumulation for the current irrigation system and management practices. They aim to develop a simple root zone monitoring toolkit for growers and a modelling tool and field validation system for water managers to manage root zone salinity for the Lower Murray districts.

They also plan to undertake an economic assessment of grower losses across the region under different River salinity scenarios by using previously developed salinity-yield relationships for different horticultural crops. This information is keenly sought by State government agencies who, through the Murray-Darling Basin Ministerial Council, are investing multi-million dollars in salinity mitigation works to reduce both the drinking water and irrigation water salinity in the Lower Murray region.

The outcomes of the 3 year project will be compiled in user-friendly Salinity Management Guidelines with salinity triggers that will assist the different investors to identify their temporal and spatial options for salinity management from the perspective of irrigation water salinity management for the Lower Murray region. This information, combined with the environmental and socio-economic requirements, will lead to the best 'triple bottom line' outcomes for this important horticultural region of Australia.

To view the latest results on the tri-state project and other initiatives of the National Program for Sustainable Irrigation, visit www.npsi.gov.au.

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Further Reading

Biswas, T., G. Schrale, G. Sanderson and J. Bourne (2005). Salinity Impact on Lower Murray Horticulture: Milestone 3 report.NPSI Milestone Report DEP15. 41 pp. Available on Irrigation Research CD.

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