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Real -Time Drainage Fluxes From The Root Zone By Using Capacitance Probe Data

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Introduction

Over the years growers in the Lower Murray-Darling irrigation districts have consistently reported salinity damage to horticultural crops despite the moderate irrigation water salinity. There is also anecdotal information that after leaching the salinity in the root zone remains higher than expected, perceived due to incomplete mixing of the soil solution.

A collaborative, Tri-State Salinity research project is being undertaken in the Riverland and Sunraysia to investigate the mechanism of soil salinity build up in the root zone and the resultant economic loss (Schrale and Biswas 2004). One of the aims of this project is to estimate the rate of deep drainage (DD) from the root zone. In this paper we present two approaches for assessing DD from data generated by multi-sensor capacitance probes, which are now widely used for irrigation scheduling in those horticultural districts. Capacitance probes utilise Frequency Domain Reflectometry (FDR), which is based on dielectric properties of soil water.

In the first method, DD was estimated by converting raw data for separate layers into a total soil profile water content (θ_v) and then used in a soil water balance model. The second, new method of DD estimation is by using Darcy's flux equation whereby a θ-ψ relationship was developed from soil water content data generated by two sensors, located just below the root zone.

The annual drainage volumes calculated from field capacities and water balance method varied from 181 to 569 mm or 19 to 43% of applied water. The DD derived by Darcy flux method showed both daily and seasonal variations of drainage rate; the data collected from a citrus property between 2002 and 2003 shows that a cumulative drainage of 250 mm or about 2.5 ML of leaching occurred during a period of 1 year. In general the water extraction pattern followed an inverse relationship with the soil depth whereby a maximum of 28 to 48% of total water was extracted from within the top 15 cm layer.

Methods

Hourly soil water balance method

Along with irrigation application and rainfall data, this method uses total root zone θ_v (mm) derived from the hourly measurements of capacitance probe. An example of such a probe with 5 sensors, located in a citrus orchard at Dareton, NSW is given below. The capacitance probe at this site has sensors at 5 depths, where each sensor represents a 10 cm soil layer. It is noted that these sensors have not yet been calibrated and hence the results are subject to some degree of error.

Rootzone: 90cm Date	Time	Sensor Depth (cm)					Total root zone water content (mm)	Average root zone θ_v (%)
		10	30	50	80	110		
11/12/2002	8:52	13.67	16.39	13.25	22.96	13.56	148.30	16.5

Hence the measured θ_v represent 5-15, 25-35, 45-55, 75-85, 105-115 cm of soil layers respectively. The data for 20, 40, 60, 70, and 90 cm have been interpolated from averaging the appropriate depths. Therefore, the total water content for the root zone is estimated as 13.67*1.5+ (13.67+16.39)/ 2 + 16.39+ (16.39+13.25)/ 2 + 13.25+ (13.25+22.96)/ 2*2 + 22.96+ (22.96+13.56)/ 2*0.5 = 148.30 mm.

Field capacity (FC), estimated either visually from water content data or from soil texture, is used as upper threshold limit for soil water holding capacity. Any amount exceeding this limit is subjected to leaching immediately after cessation of irrigation or rainfall. Due to visual judgement for moisture content and feel methods for soil texture, these FCs are subject to a degree of error and careful interpretation is needed. Total drainage was calculated as the sum of leaching throughout individual events.

θ-ψ Relationship and Darcy's Flux method
DD was estimated from capacitance probe sensors readings located at 0.8 and 1.1m cm for a given period of time, Δt by using Darcy's law ((Brown 2003):

$$DD = k(\theta_v)(\frac{\Delta h}{\Delta z} + 1)\Delta t$$

where, $k(\theta_v)$ (cm d^{-1}) is the unsaturated hydraulic conductivity at the water content θ_v (cm^3 cm^{-3}) of the soil layer below the rooting zone. Δh is metric potential; Δz (0.3m) is the distance between the bottom of the root zone (0.8m) and the immediate next depth's (1.1m) soil moisture monitoring points. $k(\theta_v)$was estimated using (Van Genuchten 1980) closed form of equation:

$$k(\theta_v) = k_s S_e^{1/2}\left[1-(1-S_e^{1/m})^m\right]^2$$

where k_s is the saturated hydraulic conductivity (cm d^{-1}), $S_e = \frac{\theta_v - \theta_r}{\theta_s - \theta_r}$; θ_s (cm^3 cm^{-3}) is the moisture content at saturation, θ_r is the residual water content, θ_v is the water content at which $k(\theta_v)$ was estimated; m is a fitting parameter of soil moisture release curve. For each θ_v at a given depth, the pressure head h, at that location was estimated as:

$$|h| = \frac{1}{\alpha}\left[(S_e)^{-1/m} - 1\right]^{1/n} \therefore\ n = 1/(1-m), m < 1$$ where, α is a fitting parameter.

Representative θ_s, θ_r, m and α were derived from an existing PIRSA soil moisture release curve database of 300 Mallee soils (Meissner 2004) whereas, k_s was estimated by using a USDA soil moisture characteristics model (Saxton *et al.* 1986) that required soil texture data as input.

Results and Discussion
Hourly soil water balance method
Table 1 gives crops, irrigation systems, FC, root zone depths, DD and root extraction patters for 13 irrigated properties ranging from sandy to clay loam in texture. Estimated field capacities ranged from 13 to 32% (v/v). The seasonal irrigation depths for the citrus crops ranged from 588 to 1646 mm; the associated total rainfall ranged from 235 to 284 mm. The vines had seasonal irrigation depths ranging from 440 to 1133 mm and total rainfall from 153 to 303 mm. The vines had seasonal irrigation depths ranging from 440 to 1133 mm and total rainfall from 153 to 303 mm.

Annual DD estimated using capacitance probe data for θ_v from vineyard and citrus sites during and between two irrigation seasons (2002-2004) varied from 181 to 569 mm or 19 to 43% of applied water. In general the water extraction pattern from the soil profile followed an inverse relationship with the soil depth where a maximum of 28 to 48% of total water was extracted from the top 0-15 cm layer.

θ-ψ Relationship and Darcy's Flux method
A preliminary estimate of daily and cumulative drainage volume derived from soil moisture content reading from capacitance probe sensors located below the active root zone at 0.8 and 1.1 m at a Dareton citrus site is given in Figure 16. The data collected between 2002 and 2003 shows that a cumulative drainage of 250 mm or about 2.5 ML of leaching occurred during a period of 1 year. This equates to nearly 0.17 leaching fraction of total applied volume, 14.8 ML, of irrigation and rainfall. Although this preliminary estimate is little less than the estimated leaching fraction of 0.23 obtained by the hourly water balance method the most important observation, however is the temporal variation of drainage represented by daily drainage. The daily drainage varied from nothing to 2.0 mm. The results

demonstrate a unique pattern where most of the drainage occurred during the winter months, which one would expect, and during the period of heavy irrigation practices that exceeds plant's evapo-transpiration need. The annual deep drainage estimated at the Dareton citrus site by both the methods was much lower than those reported by Rogers and Bartholic (1976) and Fares and Alva (2000) from citrus groves in Florida who reported nearly 50% of 18 ML applied water went past the root zone as deep drainage. However, the drainage at Dareton, NSW was nearly double the estimated value reported by MDBC for Riverland and Sunraysia (pers com, R Newman 2004).

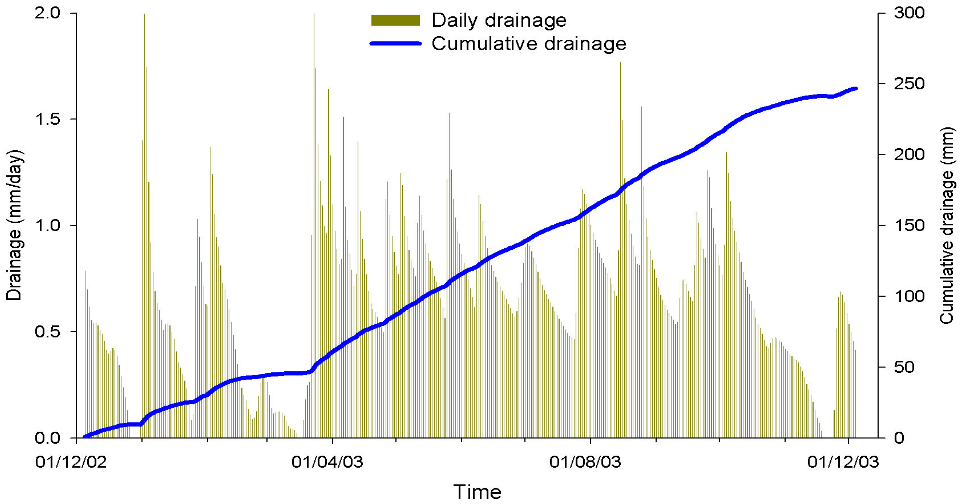

Figure 1. Deep drainage at a Dareton NSW Citrus orchard

Conclusion

Deep drainage (DD) is the prime important factor for off-site impact of irrigation on the local landscape. In the Lower Murray-Darling region DD becomes recharge to the underlying highly saline aquifers and accelerates the natural saline seepage into the Murray River. There is already a large network of capacitance probes in the Lower Murray orchards and vineyards. It is possible to calculate seasonal fluctuation of DD from θ_v readings of a capacitance probe's two consecutive bottom sensors located just below the root zone. This requires θ-ψ relationship and unsaturated hydraulic conductivity estimation if one has knowledge of soil moisture release curve and saturated hydraulic conductivity. It is proposed to calibrate the sensors and validate the results with those from conventional methods of water balance measurement and drainage meter.

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Table 1. Deep drainage and root water extractions from 13 citrus and vine properties in Sunraysia region with varying irrigation system, root depth and FC

Site	Crop and irrigation system	FC %	Root zone Depth (cm)	Irrigation mm	Rain mm	**DD mm**	Root Depth/Extraction patterns								
							0-15	15-25	25-35	35-45	45-65	65-75	75-90		
1	Dareton navel citrus -Drip	13	90	1040	284	569	0.28	0.15	0.14	0.13	0.18	0.05	0.06		
							0-15	15-25	25-35	35-45	45-55	55-75	75-85	85-90	
2	Dareton Satsuma ctrus-uc[*] Sprinkler	18	90	1003	284	515	0.57	0.22	0.05	0.05	0.04	0.04	0.03	0	
							0-15	15-25	25-35	35-45	45-65	65-75	75-95	95-100	
3	Dareton Mintill vines Drip	18.2	100	588	284	262	0.2	0.18	0.16	0.15	0.2	0.05	0.06	0	
							0-15	15-25	25-35	35-45	45-65	65-75	75-90		
4	Dareton Mintill vines Sprinkler	18.5	90	440	284	181	0.37	0.19	0.15	0.11	0.14	0.03	0.02		
							0-15	15-25	25-35	35-45	45-55	55-75	75-85	85-95	95-110
5	Keenan citrus -uc Sprinkler	20	110	1646	284	618	0.23	0.14	0.13	0.12	0.13	0.16	0.03	0.02	0.03
							0-25	25-35	35-45	45-65	65-75	75-90			
6	Wingara shiraz vines-SS[**] Drip	20	90	560	228	276	0.42	0.15	0.13	0.19	0.08	0.03			
							0-15	15-25	25-35	35-45	45-55	55-75	75-85	85-90	
7	Dareton Nova citrus-uc Sprinkler	21	90	1197	284	341	0.44	0.19	0.1	0.08	0.07	0.09	0.03	0	
							0-15	15-25	25-35	35-60					
8	Robertson1 vines-ucSprinkler	21	60	638	272	282	0.36	0.2	0.17	0.27					
							0-15	15-25	25-35	35-55	55-65	65-90			
9	Keenan navel citrus-uc Sprinkler	24	90	588	235	230	0.48	0.17	0.1	0.13	0.05	0.07			
							0-15	15-25	25-35	35-60					
10	Sam Cross citrus-uc Sprinkler	30	60	1056	272	345	0.5	0.21	0.11	0.19					
							0-15	15-25	25-35	35-45	45-55	55-65			
11	Farnsworth vines-uc Sprinkler	31	65	686	284	213	0.47	0.22	0.12	0.09	0.07	0.04			
							0-15	15-25	25-35	35-60					
12	Robertson2 vines-ucSprinkler	32	60	641	272	274	0.44	0.23	0.17	0.15					
							0-15	15-25	25-35	35-50					
13	Peter Hammond citrus-uc Sprinkler	32	50	826	303	215	0.49	0.23	0.14	0.14					

[*]uc sprinkler=under cover sprinkler [**]SS=sub-surface