

## Catchment Scale Water and Soil Balance Modelling in Southern Australia

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**Abstract:** Land clearance for agricultural production in parts of southern Australia has resulted in increased deep drainage and consequently, shallow saline watertables. The saline waters have caused deterioration in soil and water quality and reduction in agricultural production. The water use of three pastures was studied over two years. It was found that newly sown lucerne halves the amount of deep drainage compared with the established cocksfoot pasture that most farmers have sown (average deep drainage below lucerne was 7% of annual rainfall).

**Keywords:** dryland salinity, water balance, pastures, drainage

### 1 Introduction

Land degradation affects vast areas of potentially productive land in the agricultural regions of southern Australia. Most land degradation, including dryland salinity, waterlogging and water erosion, has been caused by the widespread clearance of perennial native vegetation and its replacement with mainly annual crops and pastures. This has led to a drastic change in the hydrology of agricultural landscapes. It is widely acknowledged that groundwater recharge under introduced annual crops and pastures, is significantly greater than that which occurs under natural vegetation (Kennett-Smith *et al.*, 1993).

Duplex soils, sands or loams over clays, occupy a large percentage of the southern Australian agricultural region (Chittleborough 1992). Their chemical and physical properties vary along a toposequence from crest to flat (Tennant *et al.*, 1992). Duplex soils are particularly susceptible to land degradation when cleared for agriculture. Degradation on duplex soils is exacerbated by the development of rapidly fluctuating perched water tables on slowly permeable subsoil horizons (Cox and McFarlane 1995). On some sloping duplex soils, significant quantities of water can travel as both overland flow and as throughflow on top of heavy clays (Fleming and Cox 1998). This can increase the risk of waterlogging and soil erosion on low slopes. On 'leaky' duplex soils, groundwater recharge can mobilise stored salts and bring them into the root zone, particularly in the lower slopes and flats (Fig. 1.; Cox *et al.*, 1996). The chemical and physical properties of these duplex soils may then change over time (Fitzpatrick *et al.*, 2000) often increasing their susceptibility to water erosion.



**Fig. 1** A nest of piezometers installed in a saline discharge site

It is apparent then that catchment water balances need to be changed so that less deep drainage occurs (Gregory *et al.*, 1992). One option for achieving this may be changed agronomic practices. Lucerne (*Medicago sativa* cv. Aquarius), phalaris (*Phalaris aquatica* cv. Sirosa), and cocksfoot (*Dactylis glomerata* L.) are commercially available pasture species in South Australia. Previous studies of these pasture species on flat land have shown considerable variation between species in their growth and soil water use (Crawford and Macfarlane 1995; Lolicato 2000).

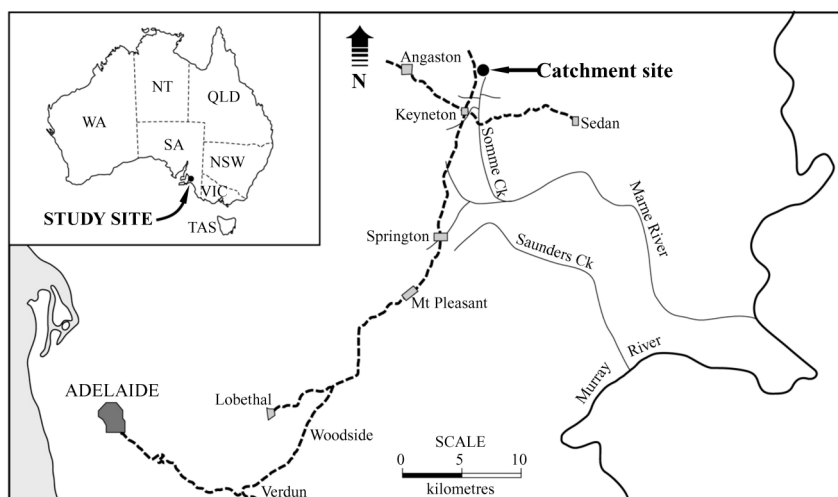
## 2 Materials and methods

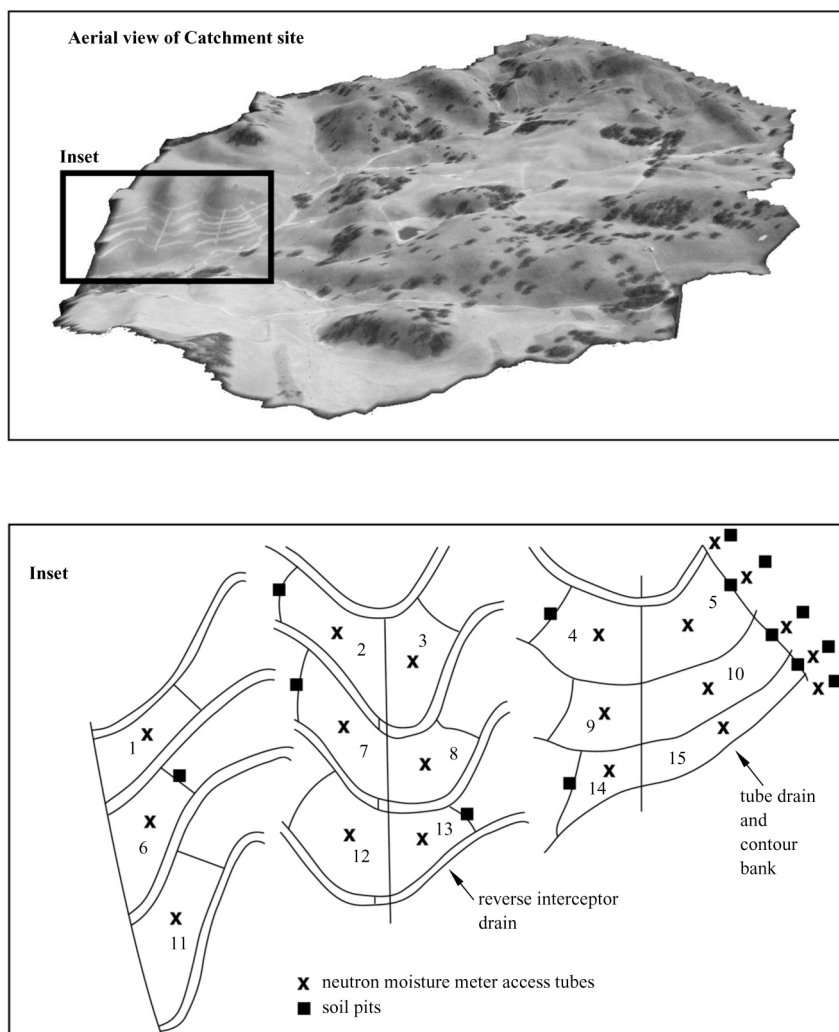
The water use of three pasture types (newly sown lucerne and phalaris, and established cocksfoot) were compared in 15 plots in a catchment in the Mt Lofty Ranges, South Australia (Fig. 2). The study site had sloping (less than 14%) duplex soils. To sample, describe and classify the soils, pits were dug within several plots as well as 5 sites along a toposequence (flat to crest) alongside the plots (Fig. 2). The aim of this study was to delineate the water pathways (e.g. evapotranspiration, overland flow and throughflow) in the catchment and to supply farmers with the best pasture option for minimising deep drainage. Deep drainage was calculated from Equation 1 using the method of Ward *et al.* (2001).

$$DD = P - ET - OF - TF - \Delta S \quad (1)$$

where  $DD$  = deep drainage,  $P$  = precipitation,  $ET$  = evapotranspiration,  $OF$  = overland flow,  $TF$  = throughflow,  $\Delta S$  = change in soil water. All units are in mm.

A weather station was installed to measure rainfall and calculate potential evapotranspiration. Drains were installed with v-notch weirs or tipping buckets to quantify overland flow and throughflow from each pasture treatment (Fig. 2 and 3; Cox and McFarlane 1995). Changes in soil water content were measured fortnightly by neutron moisture meter (NMM). Thus, aluminium access tubes were installed to 1.8 m depth in the centre of each plot, and also at five locations along the toposequence, using the method of Greacen (1981). Deep drainage was also modelled using TOPOG-IRM (Dawes and Hatton 1993) and the results compared with those calculated. Water samples were regularly collected from each drain, and also from soil solution samplers, which were installed below the rootzone, on the upper, mid and lower slope along the toposequence adjacent to the drains (Fig. 4). The chemistry of all samples were analysed using standard techniques (described in Cox and Ashley 2000) and loads calculated from concentrations and flows.

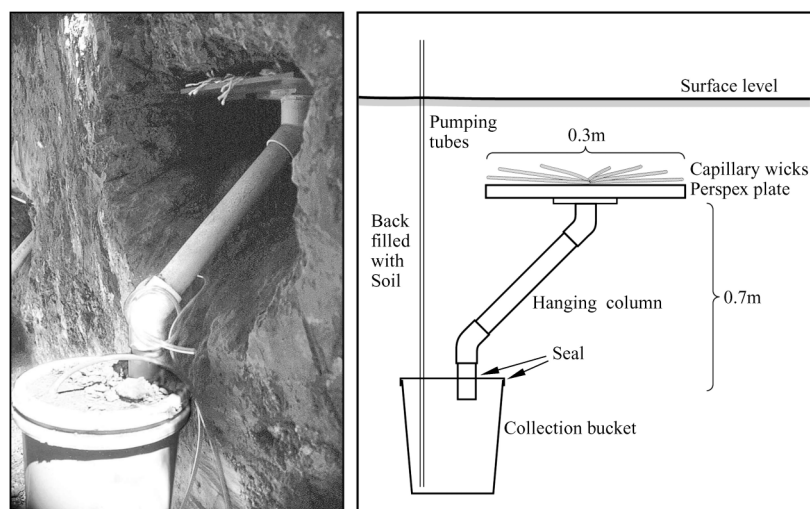




**Fig. 2** Location of the catchment and plot site details



**Fig. 3** View of plot site



**Fig. 4** An example of instrumentation designed to collect deep soil water samples below the root zone

### 3 Results and discussion

#### 3.1 Rainfall

Annual rainfall was very close to the average (544 mm) in 1996 and 27% below average in 1997.

#### 3.2 Soils

The same sequence of soils was generally found down all transects, from crest to flat. The soils were mostly Chromosols and Sodosols, with a Dermosol on one upper slope (Table 1). The topsoils were loamy sand to clayey sand or sandy loam (with depth) at all positions on the slope and were often bleached, indicating throughflow may be important. Subsoils were clays.

#### 3.3 Water balance calculations

On average, deep drainage below lucerne (over two years) was 59 mm (about 7% of rainfall; Table 1). However, deep drainage varied from 156 mm (17% of the rainfall) to  $-50.5$  mm (indicating the lucerne used water from below 1.8 m). The low water use of lucerne in one plot on the lower slope (13) could have been due to subsoil root constraints. Deep drainage below phalaris ranged from 31 mm to 148 mm and below cocksfoot from 98 mm to 148 mm. On average, lucerne used more water than phalaris or cocksfoot resulting in least deep drainage.

**Table 1** Deep drainage below 1.8 m (March 1996 to December 1997)

Plots	Slope position	Soil classification	Calculated deep drainage (mm)	Calculated deep drainage (% rainfall)
<i>Lucerne</i>				
3	Upper	Chromosol	65.1	7.3
4	Upper	Chromosol	49.9	5.6
7	Mid	Chromosol	72.0	8.0
10	Mid	Chromosol and sodosol	60.3	6.7
13	Lower	Chromosol	155.5	17.4
15	Lower	Chromosol	$-50.5$	$-5.6$
<i>Average</i>			58.7	6.6

(continued Table 1)

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<i>Phalaris</i>				
2	Upper	Dermosol	148.4	16.6
5	Upper	Chromosol	109.5	12.2
8	Mid	Sodosol	100.5	11.2
9	Mid	Chromosol	52.9	5.9
12	Lower	Sodosol	31.1	3.4
14	Lower	Sodosol	84.7	9.5
<i>Average</i>			87.9	9.8
<i>Cocksfoot</i>				
1	Upper	Sodosol	137	15.3
6	Mid	Sodosol	147.8	16.5
11	Lower	Sodosol	97.6	10.9
<i>Average</i>			127.5	14.2

### 3.4 Modelling results

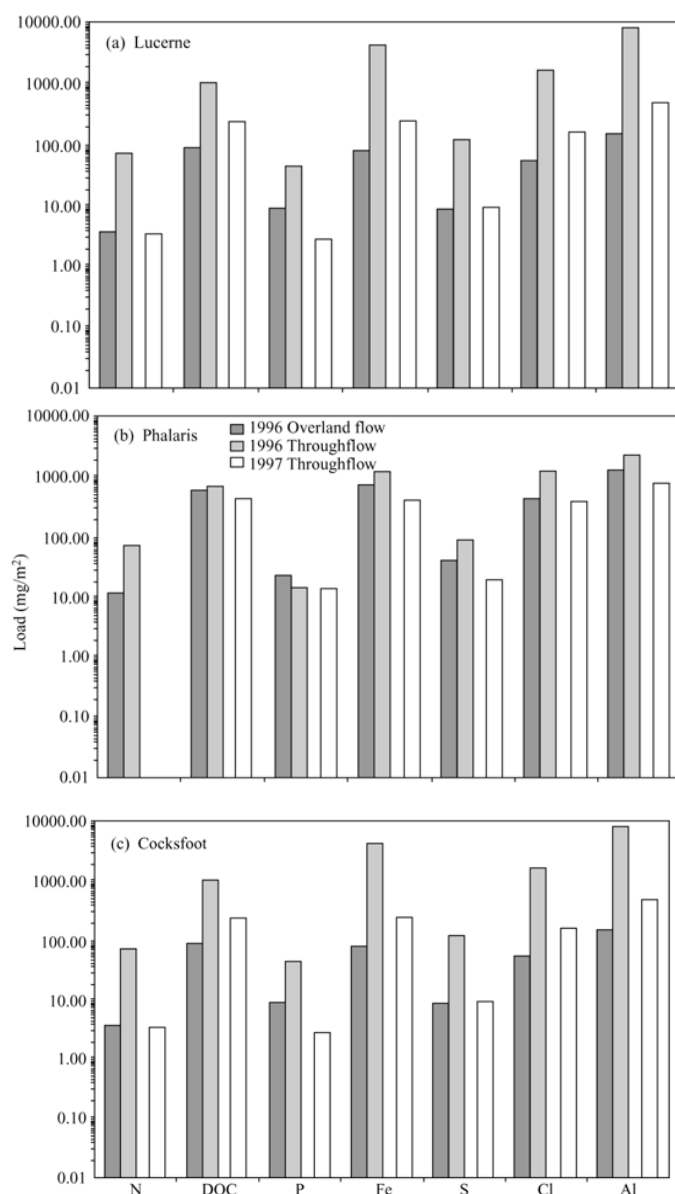
TOPOG-IRM modelling indicated that on all parts of the slope there was substantial deep drainage under the existing pasture (up to 29% of annual rainfall), with much reduced deep drainage under phalaris and lucerne. The model generally overestimated the deep drainage under cocksfoot (e.g. on the mid slope 263 mm was modelled compared with 148 mm from the water balance calculation). The model predictions for deep drainage under phalaris were within the range calculated. In contrast, the model generally underestimated the deep drainage below lucerne. However, the modelling showed deep drainage can be substantially reduced, by farmers planting phalaris or lucerne and this was consistent with the water balance calculations.

**Table 2 Average water balance (mm) over 0—1.8 m soil depth for different pasture/slope treatments(March 1996 to December 1997)**

	Cocksfoot			Phalaris			Lucerne		
	Upper slope	Mid slope	Lower slope	Upper slope	Mid slope	Lower slope	Upper slope	Mid slope	Lower slope
P	897	897	897	897	897	897	897	897	897
ET	752	755	826	806	785	872	878	877	870
OF	2	2	18	1	2	40	1	43	1
TF	8	18	74	8	44	14	13	13	29
ΔS	-59	-141	-102	19	-32	-50	44	26	-49
DD	194	263	81	63	98	21	-39	-62	46

### 3.5 Water quality

Figure 5 shows the average losses of nitrate (N), dissolved organic carbon (DOC), phosphorus (P), iron (Fe), sulfur (S), chloride (Cl), and aluminium (Al) in overland flow and throughflow off the (a) lucerne, (b) phalaris and (c) cocksfoot plots. In general, the highest losses were in the wettest year (1996) in throughflow from the cocksfoot pastures. However, replacing the cocksfoot pasture with lucerne or phalaris will result in an initial increase in the loss of elements (compared with the established cocksfoot). As lucerne and phalaris grow and develop a deep root system, water use will increase and flow will be reduced. Thus it is expected that the high losses are only short term.

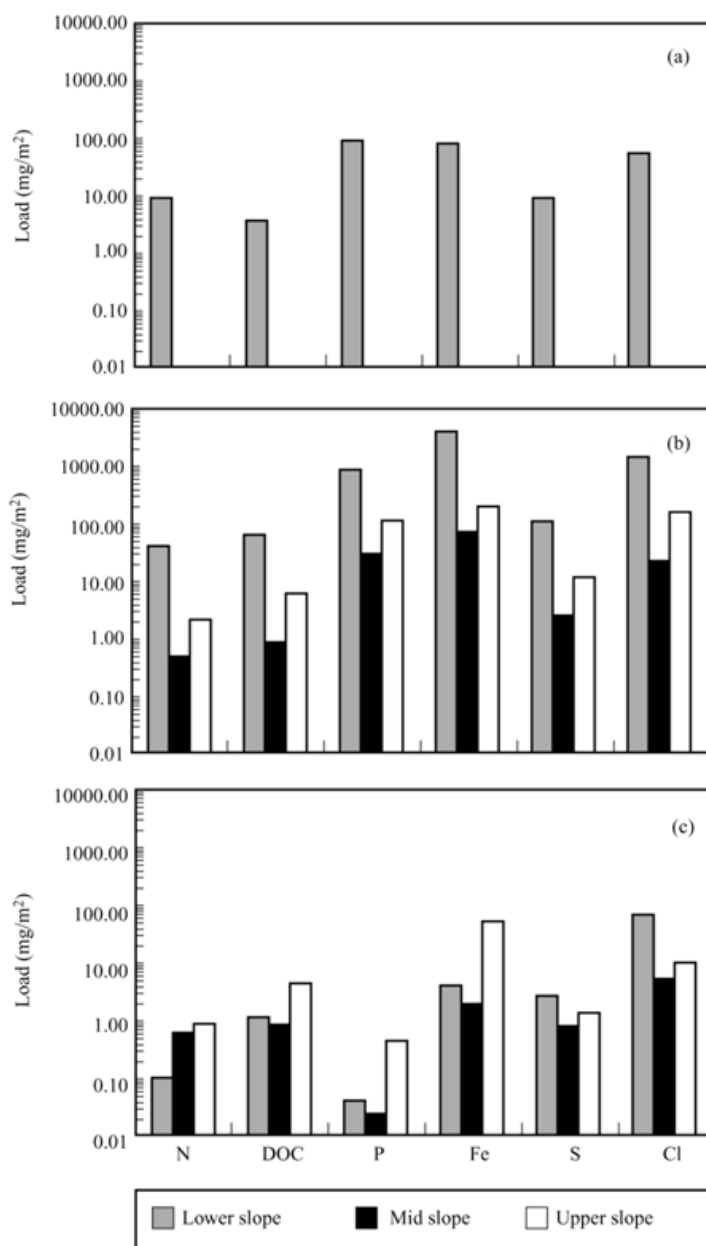


**Fig. 5** Average measured losses of nitrate (N), dissolved organic carbon (DOC), phosphorus (P), iron (Fe), sulfur (S), chloride (Cl), and aluminium (Al) in overland flow and throughflow off the (a) lucerne, (b) phalaris and (c) cocksfoot plots. Note: there was no overland flow in 1997.

Figure 6 shows losses of N, DOC, P, Fe, S, Cl, and Al from modelling of (a) overland flow, (b) throughflow and (c) deep drainage on lower, mid and upper slopes under cocksfoot. Greatest losses of chemicals occur in throughflow on the lower slopes.

#### 4 Conclusions

Farmers are now advised to plant more lucerne and/or phalaris and include these pastures in their crop rotations to reduce deep drainage. However this may result in an increase in the loss of chemicals until the pastures are well established.



**Fig. 6** Losses of chemicals from modelled (a) overland flow, (b) throughflow and (c) deep drainage on the lower, mid and upper slopes under the cocksfoot pasture.

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