Deep Drainage under irrigated cotton farming systems in New South Wales estimated with the chloride mass balance method

TimWeaver[1,2], Nilantha Hulugalle[1] and Hossein Ghadiri[2]

[1]Australian Cotton Cooperative Research Centre and NSW Department of Primary Industries, Narrabri, NSW
[2]School of Environmental Sciences, Griffith University, Nathan, QLD

Introduction

Deep drainage is essential for the removal of salts from the reach of crop root systems. The disadvantages are less water which could be used by the crop and the removal of essential nutrients transported the draining water. There are also concerns for the movement of salts and nutrients into groundwater. Shallow water tables that were reported by Willis *et. al.* (1997) are examples of excessive deep drainage and illustrate the dangers of irrigation on lighter soils.

Several researchers have used chloride mass balance models (CMB) to estimate deep drainage under irrigated crops and pastures in NSW (Slavich *et. al.* 1995; Willis, 1995; Willis and Black 1996; Willis *et al.* 1997). Slavich *et. al.* (1995) studied the effects of gypsum application on deep drainage in rice bays on a heavy grey clay using CMB. Deep drainage ranged from 514 mm/yr with zero gypsum up to 905 mm/yr with 7.5 t/ha of gypsum. Willis *et. al.* (1997) found that deep drainage in irrigated cotton was 236 mm/yr under the grey cracking clay and 145 mm/yr under the red brown earth. Both sites received 758 mm of irrigation and 630 mm of rainfall, indicating leaching fractions of 17% and 11%, respectively. Lower drainage under the red brown earth was due to lower subsoil hydraulic conductivity and the presence of a shallow water table.

Hood *et. al.* (2004) compared deep drainage results between CMB (32 mm/yr), SaLF (21 mm/yr), lysimeters (minimal) and water balance (<60 mm/yr). Drainage values estimated with the CMB was comparable to the other methods, with the lysimeter having the least drainage, although it had only been recently installed and required a settling in period. Zischke and Gordon (2000) compared CMB with SodiumSaLF and SODICS deep drainage estimates for two sites in the lower Namoi Valley. The estimates ranged from 18 to 146 mm/yr for the steady state CMB, 15 to 44 mm/yr for the SodiumSaLF model and 9 to 122 mm/yr for the SODICS model.

The research work that is being undertaken in the Namoi Valley uses the same methods used by Slavich *et al.* (1995), Willis *et. al.* (1997) and Rose *et al.* (1979). Since 2000, deep drainage has been estimated at several on-farm and on-station (ACRI) trial sites utilising chloride measured in soil cores sampled at 20-40 m intervals in transects, available weather data and neutron probe measurements. Neutron probe access tubes were installed at the sites where the soil cores were removed.

Trial Sites

Three trial sites have been studied since 2000, and include two locations at the Australian Cotton Research Institute (ACRI) at Myall Vale, another site located close to Wee Waa and a site third at Merah North (2 fields). A further two sites where measurements commenced in 2002 were located near Narrabri and Boggabri. The Merah North site and Boggabri site have sodic sub-soils (ESP>15%). The site near Narrabri (3 Fields) is irrigated with treated sewage effluent and that at Boggabri, with saline/sodic bore water. 2.5 t/ha of gypsum was applied to the three fields at Narrabri in 2000 with 12 rows in each field left untreated. The drainage estimates for all five experimental sites are shown in Table 1.

Results and Discussion

At the ACRI deep drainage was estimated under three treatments at site 2. They were: a cotton-wheat standing stubble system in permanent beds (minimum tillage), and continuous cotton in permanent beds or under conventional tillage (discing, chiselling and pulling up of beds every year). The highest drainage was observed in the cotton–wheat standing stubble system that was in permanent beds (Table 1).

The conventional tillage/continuous cotton treatment had the least drainage. Rotating the cotton with wheat, in combination with permanent beds, improved soil structure, particularly pore continuity, and consequently drainage. The conventionally-tilled treatment had poorer soil structure and therefore, in comparison with the cotton-wheat rotation drainage out of the root zone was almost 3 times lower. The leaching fractions, which are a percentage of drainage at 1.2 metres to the total water inputs, were less than 10% for all three treatments (Table 1). Leaching fractions in the absence of shallow water tables should ideally be between 10-20%. At site 1 during wheat in 2001 the leaching fraction was 20%, an increase from the cotton (13) which can be explained by the improved soil structure.

The Wee Waa site is a commercially operated farm and was conventional tillage with stubble incorporation. Deep drainage was estimated under a cotton- N-fertilised wheat rotation. An increase in drainage and leaching fraction at 1.2 metres occurred after the wheat in 2001 (Table 1). Deep cracks were evident at harvest and the standing stubble was burned. Our measurements show that stubble burning released calcium (in the form of the ash) which then leached into the sub-soil, decreasing the sodium adsorption ration of the soil water, thereby improving structure and increasing drainage during the following years (mung bean in 2001/2002 and cotton in 2002/2003).

The first Merah North trial site was established in 1993 and consisted of six rotation treatments, which finished in 2000. Observations were made in three of these, the continuous cotton, cotton-wheat and cotton-dolichos rotations. After 2000 the whole site was sown with a cotton-wheat-sorghum-cotton-wheat sequence with stubble incorporated. Measurements were also undertaken in a second field which was sown with a cotton-wheat rotation where stubble was incorporated. Drainage estimates were similar under the ex-continuous cotton and ex-cotton-wheat rotations, although that under the ex-cotton-wheat was higher during the 2002/2003 cotton season (Table 1). The ex-cotton-dolichos rotation had the least drainage. The leaching fractions for all three ex-treatments were well below ideal (Table 1). A sodic sub-soil, combined with the ex-rotation treatments affected drainage, reducing the leaching fraction particularly in the ex-cotton-dolichos.

Table 1. Water inputs (mm) and deep drainage (mean ±standard deviation) out of the 1.2 m depth (mm). The Leaching Fractions are shown in brackets.

Site and Cropping System	2000/2001	2001	2001/2002	2002	2002/2003
ACRI					
Site 1	**Cotton**	**Wheat**	**Fallow**		**Cotton**
Water Input	717	312	220		825
Standing wheat stubble/Permanent beds	90 ± 31 (13)	62 ± 21 (20)	-1 ± 1 (0)		70 ± 32 (8)
Site 2					**Cotton**
Water Input					825
Conventional. Till/Continuous cotton					24 ± 12 (3)
Permanent beds /Continuous cotton					41 ± 17 (5)
Permanent beds/Cotton-wheat*					67 ± 27 (8)
(*cotton sown into standing wheat stubble)					
Wee Waa	**Cotton**	**Wheat**	**Mung Bean**	**Fallow**	**Cotton**
Water Input	979	541	439	81	1025
Wheat Stubble Incorporated	70 ± 11 (7)	35 ± 9 (6)	143 ± 25 (28)		159 ± 30 (16)
Merah North	**Cotton**	**Wheat**	**Sorghum**	**Fallow**	**Cotton**
Field 1					
Water Input	1000	630	397	79	1265
Continuous cotton	64 ±31 (6)	39 ± 23 (6)	47 ± 42 (12)	0 ± 3 (0)	50 ± 42 (4)
Cotton-wheat	55 ± 36 (6)	36 ± 28 (6)	40 ± 25 (10)	0 ± 2 (0)	62 ± 66 (5)
Cottond-dolichos	14 ± 11 (1)	11 ± 5 (2)	12 ± 3 (3)	3 ± 1 (4)	19 ± 11 (2)
Field 2			**Cotton**		
Water Input			923		
Cotton-wheat			25 ± 16 (3)		
Boggabri					**Cotton**
Water Input					638
Standing wheat stubble/permanent beds					11 ± 5 (2)
Wheat stubble incorporated/permanent beds					4 ± 2 (0.6)
Narrabri - irrigated with treated sewage effluent			**Cotton**		
Water Input			286		
Field 1 - 2.5 t/ha Gypsum			46 ± 17 (16)		
No-Gypsum			44 ± 7 (15)		
Field 2 - 2.5 t/ha Gypsum			25 ± 12 (9)		
No-Gypsum			29 ± 8 (10)		
Field 3 - 2.5 t/ha Gypsum			122 ± 97 (43)		
No-Gypsum			51 ± 53 (18)		

Two treatments were assessed at the Boggabri site, *viz.* cotton sown into standing wheat stubble and cotton sown after wheat stubble was incorporated. Drainage was higher under the standing stubble system. However, when compared with the Wee Waa and ACRI sites it is very low with very low leaching fractions. There were only 3 irrigations during the 2002/2003 cotton season and cotton yields were very low (3-4 ba/ha). Soil salinity was high at this site, and it is likely that the 3 irrigations were insufficient to leach accumulated salts out of the root zone.

At the site near Narrabri 3 fields were monitored. Fields 1 and 2 showed similar values of drainage (Table 1) for both the gypsum and non-gypsum treatments. Drainage in Field 3, however, was increased by the application of gypsum with higher variability when compared to the other 2 fields. Higher sand content in both the gypsum and non-gypsum treatments in Field 3, which may be due to a prior stream, probably caused this increased variability. The leaching fractions were high in this field as well when compared to fields 1 and 2.

The deep drainage estimates in Table 1 are comparable to those of Zischke and Gordon (2000), but are lower than those of Willis *et. al.* (1997). This is probably because the soils studied by Willis *et. al.* (1997) were lower in clay content when compared to those in the lower Namoi Valley.

Conclusions

Our results show that minimum tillage (permanent beds) and rotation with a cereal crop such as wheat facilitates higher through drainage and leaching. However, more field data on rates of deep drainage is required for different land management systems and options, particularly those which minimise root zone salinization. This is beneficial where water quality is poor due to large concentrations of chloride and other mineral salts. Knowing which rotation crop increases deep drainage will be beneficial in improving root zone soil quality and eventually yield.

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