Deep drainage calculated from soil chloride under a long-term rainfed crop rotation experiment in the Murray Mallee, Australia

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Abstract

The use of naturally occurring chloride in the soil to estimate long-term average deep drainage rates is a useful tool where annual drainage rates are low. In environments, such as the temperate semi-arid zones, directly measuring deep drainage is problematic because the errors of measurement are close to the annual drainage rates. We report changes in soil chloride for an 11-year period starting from 1990 under a long-term rainfed cropping rotation experiment at the Mallee Research Station, Walpeup, Australia. Over the 11-year period, the cumulative net drainage at the sampling depth of 9 m for the fallow-wheat rotation was 54 ?25 mm/yr compared with 1.3 ?23 mm/yr for the pasture-fallow-wheat (PFW) and –1.8 ?36 mm/yr for the pasture-wheat (PW) rotation. There was a tendency for a small upward movement of water in the upper parts of the profile, but below the nominal root zone depth of 1 m. The work corroborates the earlier findings that fallow every second year at this site causes significantly more drainage than a PW rotation. What is interesting is that the PW had a small net upward movement over the same period. The PFW rotation had a slightly positive drainage term at 9 m but clearly it was upward for much of the upper profile. It seems that a fallow every third year at this site over the 11 years did not contribute greatly to deep drainage, indeed the differences between PFW and PW in the original analysis of 11 mm/yr are considered manageable.

Media summary

Soil chloride measurements under long-term rainfed cropping show that if long fallows in rotations are eliminated drainage can be near zero.

Key Words

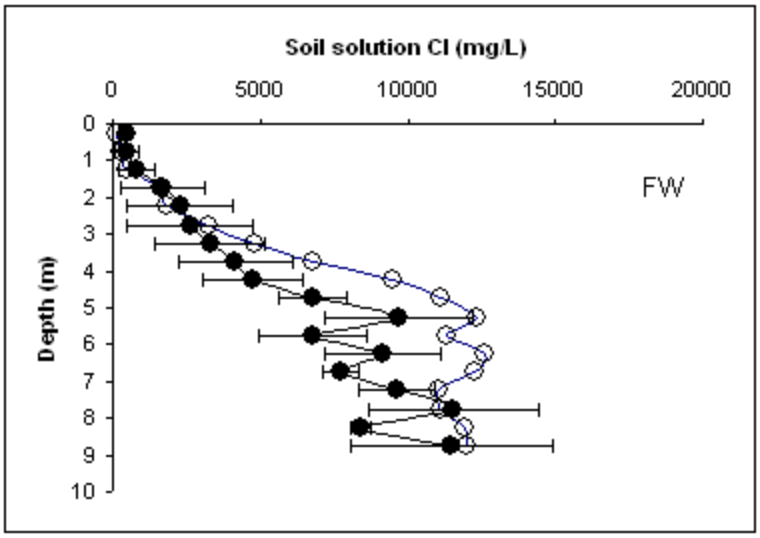
Fallow, wheat, pasture, recharge, groundwater.

Introduction

Long periods of fallow in southern Australia are known to increase the potential for higher recharge to deep aquifers. This is considered undesirable because the underlying groundwater is very saline and when such groundwater approaches the surface, serious loss of agricultural production occurs in addition to the degradation in water quality that occurs along and in the nearby rivers. The use of soil chloride measurements to estimate long-term average deep drainage rates is a useful tool where annual drainage rates are low (Allison and Hughes, 1983; Walker *et al*., 1991). In environments, such as the temperate semi-arid zone, directly measuring deep drainage is problematic because the errors of measurement are close to the annual drainage rates.

We have previously made estimates of the contribution that fallow (O'Connell *et al*., 1995) and various tillage options (O'Leary, 1996) make to potential recharge for Mallee and Wimmera cropping regimes. These studies compared the differences in deep drainage calculated from soil chloride and water profiles taken at one time by averaging drainage over the period that the plots from the various treatments were monitored (e.g. 8 and 10-72 years, respectively). Fallowing one year in three, compared with continuous cropping on a fine-textured clay (Wimmera site), increased drainage by 6 mm/yr. On a sandy loam (Mallee site), drainage rates ranged from 11 to 56 mm/yr more from fallowing one year in three and every

second year, respectively compared to a non-fallow regime (pasture-wheat - PW). On the fine textured clay (Wimmera site), stubble retained no-till fallows drained 19 mm/yr more than conventional tilled fallows without stubble, whilst stubble retained sub-surface tilled fallows drained 4 mm/yr more than conventional tilled fallows without stubble.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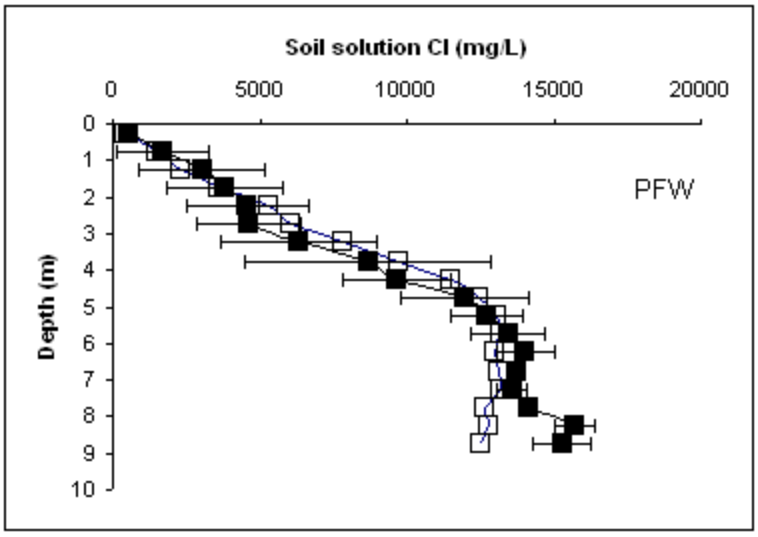
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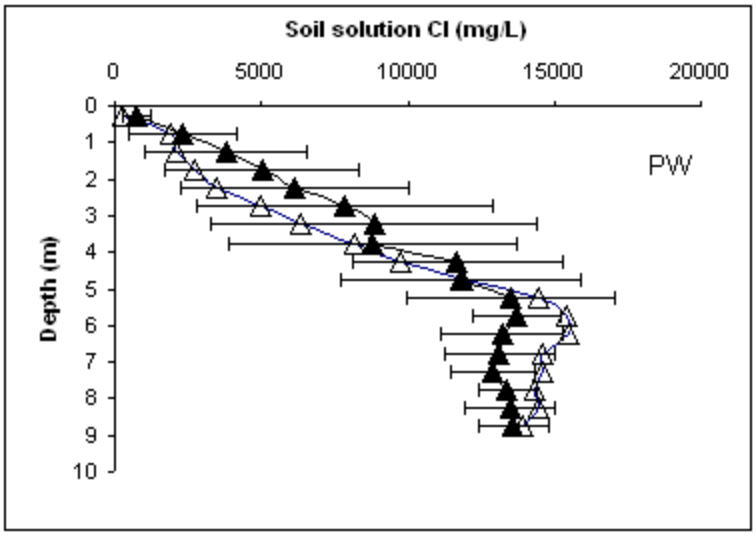
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Figure 1. Profiles of mean chloride concentration of soil solution under fallow-wheat (FW, ○, ●), pasture-fallow-wheat (PFW, □, ■) and pasture-wheat (PW, △, ▲) crop rotations at the Mallee Research Station, Walpeup in 1990 from O'Connell *et al*. (1995) (open symbols) and 2001 (closed symbols). Error bars represent ? one standard error.

We have now resampled the Mallee site and report changes in deep drainage for an 11-year period since the original sampling in 1990 at the Mallee Research Station, Walpeup, Australia. We aimed to estimate drainage rates under each experimental plot and rotation where measurements were made in 1990 and again in 2001. Absolute rates, rather than differences between treatments, are important as there have been recent suggestions that significant, although small, upward movement of water from below the root zone may be an important component of the water balance in this semi-arid region (Diaz-Ambrona *et al*., 2001).

Methods

A long-term field experiment at the Mallee Research Station, Walpeup (35° 07'S, 141° 59'E, elev. 85 m) was established in 1982 to investigate the long-term effects of tillage and rotation (Incerti *et al*., 1993; Latta and O'Leary, 2003). Machinery breakdown and wet weather during soil sampling in 2001 prevented the collection of a fully replicated data set identical to that collected in 1990 (see O'Connell *et al*., 1995). This prevented a plot-by-plot analysis and a designed Analysis of Variance, but we were able to compare an analysis of rotation-by-rotation. Sample numbers for each rotation ranged from a total of 99 to 134. Each rotation had at least 2 complete observations to 8.75 m and 12 observations to 2.25 m for each 0.5 m interval. Standard errors of the measurements from multiple observations were used to assess statistical significance and determine confidence intervals for drainage rates. The combined chloride and water method of Walker *et al*. (1991) was used to calculate average drainage between 1990 and 2001 for each rotation.

Results

Over the 11-year period the average annual rainfall of 332 mm was close to the long-term average of 338 mm. Soil solution chloride concentration changes with depth under different cropping regimes from the original analysis in 1990 (O'Connell *et al*., 1995) and in 2001 (this study) showed important features (Figure 1):

- the chloride concentration of the soil water solution increases with soil depth to a reasonably constant value (10-15 x 10^3 mg/L) under all treatments at approximately 5 m,
- greater downward displacement of chloride (dilution) is more apparent under the fallow-wheat (FW) regime compared to the other cropping systems (pasture-wheat - PW and pasture-fallow-wheat - PFW) and,
- some evidence of upward displacement of chloride under the PW cropping regime, despite large variance.

Assuming piston flow, our data suggests that the displacement of chloride equate to both negative (upward) and positive (downward) percolation (Figure 2). The water movement between our 0.5 m layers was mostly positive for the FW rotation (Figure 2a). The integral with respect to depth estimates the cumulative net drainage from the surface to the sampling depth. Over the 11-year period, the cumulative net drainage at the sampling depth of 9 m for the FW rotation was 54 ?25 mm/yr compared with 1.3 ?23 mm/yr for the PFW and –1.8 ?36 mm/yr for the pasture-wheat PW rotation (Figure 2b). There was a tendency for a small, but statistically near zero, upward movement of water in the upper parts of the profile, but below the nominal root zone depth of 1 m.

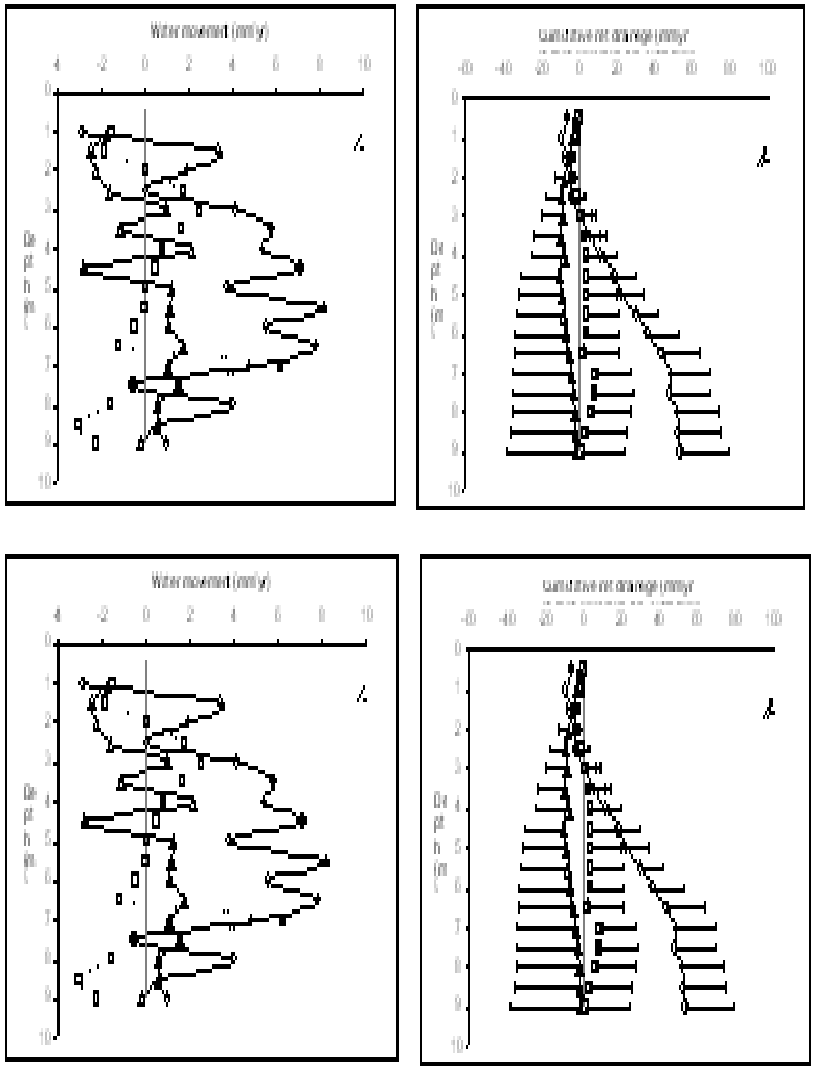

Figure 2. Profiles of water movement between 0.5 m layers (a) and cumulative net drainage from the surface to depth (b) under fallow-wheat (FW, ○), pasture-fallow-wheat (PFW, □) and pasture-wheat (PW, ∆) crop rotations at the Mallee Research Station, Walpeup for the period 1990 to 2001. Error bars represent + or - one standard error.

Discussion

The data reinforces the earlier agronomic recommendation for dryland salinity control by O'Connell *et al*. (1995) to reduce the frequency of fallowing in the Mallee croplands. Earlier work by Allison and Hughes (1983) in a neighbouring paddock under the same cropping regime (PFW rotation) shows close agreement to our 1.3 mm/yr (*c.f.* 3-4 mm/yr). Similarly, a drainage rate of ≈5 mm/yr under PFW has been modelled by Zhang *et al*. (1999). In a nearby experiment, of similar rotation (fallow-wheat-peas), measurements from lysimeters from 1993 to 1998 indicated drainage at 1.7 m depth of 0.24 mm/yr and for the period 1998 to 2001 6.7 mm/yr (O'Connell *et al*., 2003). One problem in interpreting deep drainage data is to know the depth at which it applies, thus the notion of an upward movement below the root zone is not surprising. The mechanism for upward flow is open to conjecture, although both liquid and vapour phase movement are probably involved. Despite the numerous artefacts accompanying field experiments, such as the use of a slashed-for-grazed pasture, our analysis is consistent with previous work. It, therefore, gives confidence that the major contributor to deep drainage in the Mallee rainfed cropping

regions is long fallow and that continuous cropping with or without pasture is a way to substantially reduce deep drainage.

Conclusion

The work corroborates the earlier findings that fallow every second year at this site causes significantly more drainage than a PW rotation. What is interesting is that the PW had a small net upward movement over the same period. The PFW rotation had a slightly positive drainage term at 9 m but clearly it also was upward for much of the upper profile. It seems that a fallow every third year at this site over the 11 years did not contribute greatly to deep drainage, indeed the differences between PFW and PW in the original analysis of 11 mm/yr are considered manageable by agronomic means.

Acknowledgments

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