Lucerne creates a dry soil buffer to at least 5m

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Abstract

Lucerne (*Medicago sativa* L) has been promoted for its high-quality feed during summer and for its ability to control the excessive groundwater recharge that leads to salinity. To quantify its capacity to reduce leakage below the root zone in southern Victoria, soil water beneath lucerne was measured between 2006 and 2010 at monthly intervals to a depth of 5 m as part of the EverGraze experiment at Hamilton Victoria. Equivalent measurements were also made on perennial ryegrass (*Lolium perenne* L.).

Over the 4.4 years of measurement there was net drying of the soil beneath lucerne between 2.5 and 5 m, equivalent to transpiration of 32 mm/yr. By contrast there was a net increase of 8 mm/yr at these depths under perennial ryegrass. Winter wetting fronts on the lucerne penetrated no deeper than 3 m, whereas wetting fronts under perennial ryegrass penetrated to the full depth of measurement every year except 2006, which was unusually dry. The depth of wetting beneath lucerne each year was linearly related to rainfall from June to September. Based on this relationship and long-term rainfall data (1889-2011) the maximum depth of wetting that could be expected under lucerne is 3.8 m. Since there would still be a buffer of dry soil below this depth, it can be concluded that established lucerne fully controls groundwater accessions from the area sown to it in this soil and climatic environment.

Key Words
Lucerne, perennial ryegrass, recharge, dryland salinity, chromosol, basalt plain

Introduction
Dryland salinity increased in southern Victoria following clearing for agriculture. In the Corangamite catchment, Pillai (2003) reported that 58% of classified saline land was primary salinity that would have been saline prior to agricultural development, while the other 42% was secondary salinity. The increased saline area is because the agricultural plants are predominantly winter active and allow more leakage below the root zone than the pre-agricultural vegetation. The majority of the land area consists of pastures for sheep and cattle that are typically based on either volunteer annual grasses and summer dormant cultivars of perennial ryegrass (*Lolium perenne* L.) or phalaris (*Phalaris aquatica* L.), with annual subterranean clover (*Trifolium subterranean* L.) as the principal legume (Quigley *et al.* 1992). In the more continental climate of northern Victoria, lucerne (*Medicago sativa* L) has proven to be a reliable pasture plant that substantially reduces leakage below the root zone (Ridley *et al.* 2001).

The EverGraze experiment at Hamilton was established to test the hypothesis that pasture systems that include lucerne can increase the profitability of grazing enterprises and control leakage below the root zone (Ward *et al.* 2012). A component of the experiment was a comparison between lucerne and perennial ryegrass pastures on the well-drained crests. This paper reports soil water and drainage from these treatments.

Methods
Site
The experimental site was located on the Department of Primary Industries research station at Hamilton, on a Brown Chromosol derived from basalt. The site is typical of the western basalt plain in southern Victoria. Topography is gently undulating with 3 distinct phases – crest, slope and valley. Crests have well-drained gravelly soils, while the slopes and valleys are subject to waterlogging during wet winters. Crests were planted to treatments of lucerne (cv. SARDI Seven) in October 2004 and perennial ryegrass (cv. Fitzroy) in June 2005. From February 2006 until June 2010 the area was grazed by sheep in rotations that included other pasture treatments that were sown on the slope and valley.

Measurements

Aluminium access tubes were installed to a depth of 2-5 m to enable moisture measurement using a neutron moisture meter. In each plot at least 2 holes were augered (diameter 75 mm), the access tube installed and space between the soil and tube filled by a slurry of kaolinite and bentonite following methods described by Graecen *et al.* (1981). Measurements were made every 3-11 weeks from February 2006 to December 2010. Reading depths were 0.15 m, 0.3 m, 0.5 m, 0.75 m, and 1.0 m, thereafter at intervals of 0.5 m to the bottom of the access tube. The neutron moisture meter was calibrated to volumetric soil moisture using procedures outlined by Graecen *et al.* (1981).

Statistical analysis

Two forms of statistical analysis were undertaken. Firstly, soil moisture data were analysed by linear mixed models using smoothing splines of time with a linear effect of time (Verbyla *et al.* 1999) and pasture species and neutron instrument, date and "pulse" as fixed effects and allowing for random date and tube effects. The parameter of interest here was the slope of soil moisture with time for each treatment to detect differences in the rate of wetting or drying. This analysis was undertaken for data between February 2006 and June 2010 in 5 depth increments, *viz* 0.1-1.25 m, 1.25-2.25 m, thereafter in 1 m increments to 5.25 m. Secondly, the depth of wetting beneath lucerne during each winter-spring season was determined by identifying the deepest measurement depth where soil moisture increased by 1% or more between 1 June and 30 September in at least 50% of tubes. A relationship was sought by linear regression between the depth of wetting and June-September rainfall. This relationship was used with long-term rainfall data (1880-2011) for Hamilton to determine the wetting depth over a wider range of years. The smoothing spline analysis was conducted in ASREML (Gilmour *et al*. 2006), and other analyses using Genstat 11 (VSN International, Hemel Hempstead, UK).

Results

Short-term periods of high soil water content were evident each winter in both lucerne and perennial ryegrass (Figure 1). These winter wetting fronts penetrated to a depth of 1-3 m beneath lucerne, below which was dry soil, but to at least 3 m beneath perennial ryegrass in most years. There was net drying of the soil profile beneath lucerne, particularly deeper in the profile, whereas there was net wetting at all depths under perennial ryegrass (Table 1). Lucerne achieved a drying rate of 32 mm/yr averaged over 4.4 years of measurements between the 2.25m and 5.25m depths. Predicted values from the analysis indicated a more rapid rate of drying of 67 mm/yr in this depth range for the first 2 years of the experiment, after which there was minimal change (data not shown).

The depth of wetting beneath lucerne was related to rainfall over the June to September period (Figure 2). Using this relationship with long-term rainfall data, the wetting front would exceed 3 m in 14% of years, and the maximum depth of wetting that could be expected in the wettest of years is only 3.8 m.

Table 1. Change in soil water (mm/yr) for lucerne and ryegrass, and its standard error (SE).

Depth range (m)	Lucerne	Ryegrass	SE
	Change (mm/yr)		
0.10-1.25	5.3b	7.3a	1.60
1.25-2.25	0.1b	5.7a	0.47
2.25-3.25	-16.5b	2.8a	0.59
3.25-4.25	-11.7b	2.7a	0.94
4.25-5.25	-3.9b	2.5a	0.65
Sum 2.25-5.25	-31.8	8.0	

Discussion

Lucerne developed a dry soil buffer to a depth of at least 5 m over the first 2 years of measurement. The depth of drying by lucerne was much deeper than the 3 m reported previously by Ridley *et al.* (2001). At a 3 m drying depth, recharge could be expected in 14% of years, whereas at 5 m no recharge would be expected. The rooting depth in our study was based on statistical modelling over time, whereas Ridley *et al.* (2001) used analysis of variance at set times to compare soil moisture beneath lucerne with a low water use treatment.

(a)

(b)

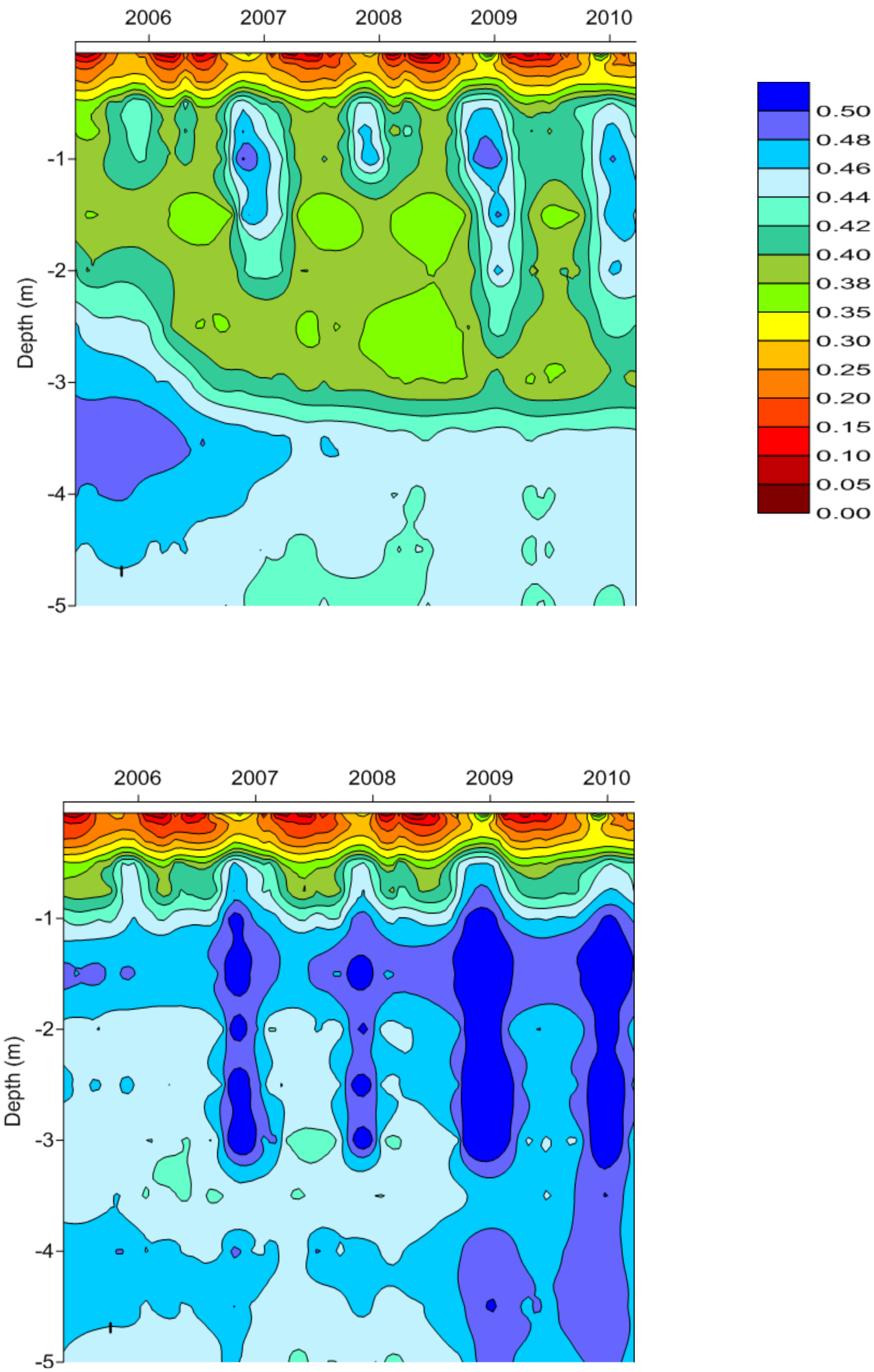

Figure 1. Volumetric soil moisture (m^3 water/m^3 soil) for (a) lucerne and (b) perennial ryegrass. Year labels are shown at 1 October each year.

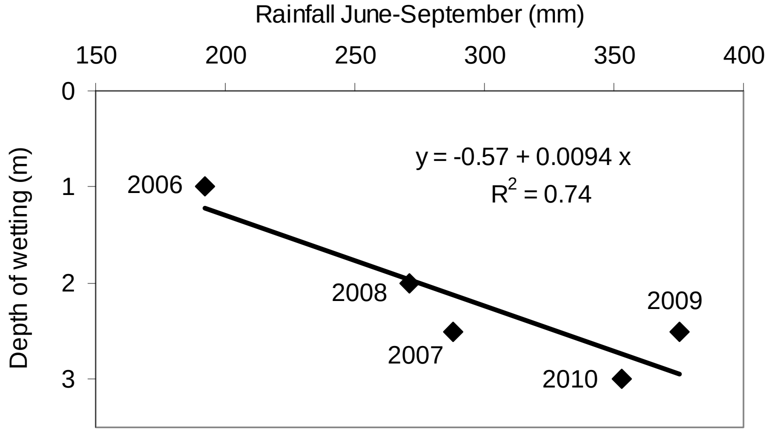

Figure 2. Depth of wetting beneath lucerne in relation to rainfall from June to September inclusive.

A factor limiting the adoption of lucerne in southern Victoria has been that its annual pasture growth has been less than that of perennial ryegrass (Saul 1988). However measurements of pasture accumulation rate in this experiment have shown no differences in annual pasture growth between lucerne and perennial ryegrass (Ward *et al*. 2012). This was because of higher growth rates from more recent lucerne cultivars. Lucerne is therefore a pasture that both controls leakage below the root zone and produces a competitive amount of annual dry matter. Furthermore, a greater proportion of its growth occurs in the summer-autumn period when pastures based on perennial ryegrass respond poorly to rainfall and there is little other animal feed of high nutritive value. Economic analyses have shown that the pasture systems containing one third lucerne had higher gross margins in dry years and similar gross margins in wetter years (K.Stott, DPI Parkville unpublished).

The empirical relationship between rainfall and the depth of wetting needs to be used with caution, because it does not account for the pasture establishment phase, nor the effects of successive wet years. In our experiment, for example, lucerne required 4.3 years from sowing to fully develop its dry soil buffer.

Conclusion

Lucerne controls the leakage of water below the root zone by developing a dry soil buffer to a depth of at least 5 m. Newer cultivars mean that the annual production of lucerne is competitive with perennial ryegrass, and is likely to achieve a much higher level of adoption in southern Victoria. This will help mitigate salinity in the region.

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