Assessing the impact of land-use on deep drainage in a Mediterranean environment in southeastern Australia

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Abstract.

The clearing of natural perennial vegetation including native grasses, trees and shrubs and the replacement with annual crops and pastures increases the amount of water stored in the soil profile, resulting in an increased risk of deep drainage. Drainage beyond the root zone of plants leads to loss of potential yield and contributes to rising water tables and the development of secondary salinity.

Field experiments were established in May 2004 to measure the water balance and then to estimate the amount of deep drainage occurring on two key ground water flow systems of the Wimmera catchment of Victoria, Australia. The experiment evaluated five land-use systems in terms of water use, rooting depth, biomass production and canopy light interception. The systems compared were lucerne, native grass pasture (dominated by *Danthonia spp.*), annual grain cropping, alley farming with either tagasaste and saltbush, compared to a 3 year fallow. Lucerne and tagasaste extracted the most water from the soil profile and had deep root systems. Native pasture extracted the least water and had a shallow root system.

Native pasture systems, despite their high conservation value, are not as effective in controlling deep drainage as other land use options tested. These pastures are relatively drought tolerant, but this was not a consequence of a deeper rooting system. Lucerne in particular was able to extract water from deeper in the profile than other systems.

Media summary

Developing farming systems that balance root depth and soil profile characteristics within particular environmental conditions reduces the potential risks of dryland salinity whilst providing an increase in grower's yields and profits.

Keywords

Water use efficiency, chloride profiles, water extraction patterns, drought, modelling.

Introduction

The farming systems of southeastern Australia are diverse, with multiple annual crop species and pastures used in rotation to spread production risk as well as provide positive interactions between phases in the rotations. Most of the farming systems replaced perennial grasslands or woodlands about 100 years ago, and there has been concern that this change from perennial to annual systems has led to a change in the hydrological balance which caused inherent salt stored in the soil to enter the groundwater system.

The Wimmera region of southeastern Australia receives approximately 25% of the annual rainfall from December to March (summer). During this period most of the landscape has no actively growing vegetation as annual crops have been harvested and the native perennial vegetation on non-farmed land is less now than 0.02% (Connor, 1966) of the current land use. Large episodic summer rainfall events usually infiltrate deeply and contribute to in-season water supply. Crops are usually sown in late autumn/early winter and begin to extract water from the usually clay loam to sandy clay loam soils (>25% clay), but the stored water from summer has often passed well below the root zone of the plants (deep drainage). This movement of water beyond the reach of roots is a major driver of dryland salinity, as soluble salts are mobilized from the stores in the parent material. These saline water tables can then appear near the surface as a result of the hydrological imbalance, which then leads to dryland salinity (White et al. 1999).

If the demand and supply of moisture could be more closely matched temporally and spatially, the potential effects of dryland salinity would be reduced, allowing growers to potentially produce more sustainable yields and generate a higher profit. We propose that this can be achieved by better matching a particular farming or vegetation system to the soil type and climate. This study (2004-2007) aimed to present growers and policy makers with estimates of the amount of deep drainage occurring under various vegetation systems, therefore allowing the development of systems that better match water demand with supply. The systems evaluated included current farming practices (annual cropping and fallowing), the currently recommend -option to control deep drainage (Lucerne), two novel alley farming systems (Saltbush and Tagasaste) and the original native pasture (*Danthonia spp*).

Methods

Experiment 1: In May 2004, a field experiment was established on a key ground water flow systems of the Wimmera catchment of Victoria (Boolite), southern Australia. It was designed as a randomized complete block, with 6 treatments per block. Each treatment plot measured 15 m x 15 m and had a neutron moisture meter access tube to a depth of 1.8 m in the center of the plot. The soil is classified as a sodosol (Isabell, 1996). The six treatments compared were lucerne (*Medicago Sativa*), saltbush (*Atriplex nummularia*), tagasaste (*Chamaecytisus proliferus*), a traditional cropping rotation for the region (Year 1: wheat (*Triticum aestivum*), Year 2: barley (*Hordeum vulgare*), and Year 3: peas(*Pisum sativum*), native pasture (Common Wallaby grass/*Austrodanthonia caespitosa*) and a chemical fallow. The tagasaste and saltbush were harvested annually to simulate a commercial grazing operation. Neutron moisture meter readings were collected monthly to assess the changes in soil moisture content. These changes in profile water storage plus rainfall were used to determine the water use of each treatment each month and these were summed progressively to give a cumulative water use for each land use option

Experiment 2: In 2005 a study was conducted to estimate the amount of deep drainage occurring under a long term cropping system (>40 years) compared with an untouched native Buloke tree belt (*Allocasuarina leuhmannii*) and a native pasture (*Austrodanthonia caespitosa*) which was established 25 years ago. The land uses were adjacent and had similar soil types and positions in the landscape. The water use patterns were estimated by determining the distribution of chloride among soil samples taken to a depth of 600 cm. Because chloride moves with water in the soil, its distribution can be used to estimate flows through a soil profile (O'Leary and O'Connell, 2004).

Results and Discussion

The average annual rainfall at the Boolite trial site is 400 mm, although during the period 2004-2007 the region has experienced decile 2 rainfall of less than 350 mm. The pattern of episodic summer rainfall however has not changed.

Experiment 1

Over the three years of measurement, lucerne used the most water of all the systems tested, and this amount was close to the total rainfall for the period (Figure 1). This water use was reflected in the biomass produced (not shown) due to the deep rooting system of lucerne and its ability to immediately respond to any available moisture. The tagasaste used 97% of the water available although it had a relatively low biomass production. The saltbush is a C4 and is essentially dormant in the winter. It used the episodic summer rainfall, converting the available moisture into biomass during in the summer months and its well established root system allowed it to quickly regenerate when harvested. The native pasture used a similar amount of water to the saltbush, although the profile distribution of the water indicated that the native pasture has a relatively shallow root system (<60 cm). The majority of this deep water was not used by the native pasture and it is probable that it has leaked past the root zone and is lost as deep drainage (O'Leary and O'Connell, 2004). Despite the relatively dry seasonal conditions during the experiment, the annual crop treatment still had unused soil water at the end of the experiment Passioura JB (1991), and this was significantly more than all the other vegetation treatments. The rapid growth of these crops occurred mainly during periods of relatively low water demand, and the rooting depths were intermediate between the lucerne and the native pastures. As a consequence, under this land use, unused water accumulates in the subsoil and flows deeper into the profile over time.

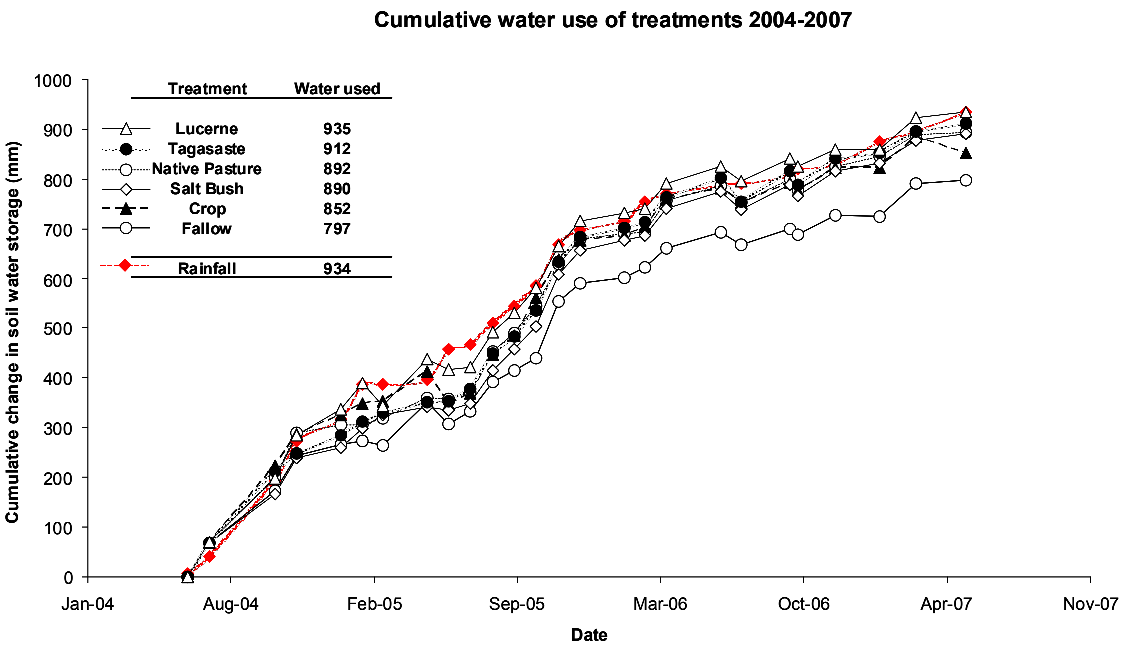

Figure 1. Cumulative monthly rainfall (mm) and the cumulative change in soil-water storage (mm) between depths 0-180cm, under the 6 treatments from 2004-2007 at Boolite.

It is clear that native pastures tested here are not able to extract water from deep in the profile, but they are able to survive periods of water deficit by becoming dormant. On the other hand, lucerne is able to use its deep roots to maintain some growth by accessing deep soil water.

Experiment 2.

In the expected root zone (0-2 m), the highest levels of chloride occurred in the tree belt, indicating maximum water use and very little movement of water (Figure 2a). The volumetric moisture contents indicate the tree belt has dried the soil to wilting point (-1500 KPa) at 25% VSM, whereas the crop and native pasture are both leaking continuously (Figure 2b).

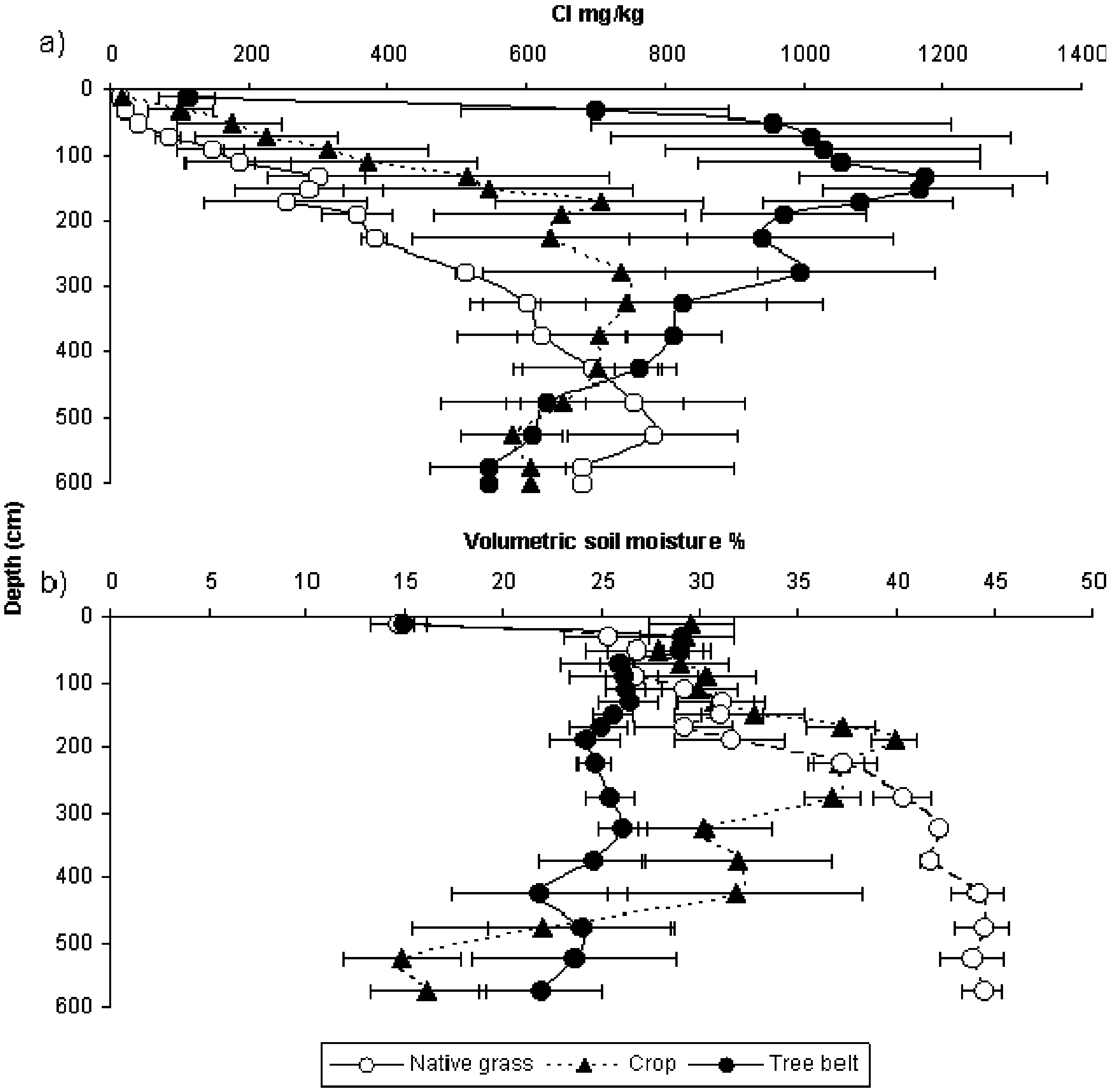

Figure 2. Distribution of chloride (Figure 2a) and water (Figure 2b) down the soil profile at Boolite under three different landuses to 600 cm.

Under the annual cropping system, where the land was in fallow since the previous crop in 2004, soil moisture content remained relatively high throughout the potential root zone. The native pasture is saturated past 100 cm indicating a shallow roots system or chemical constraint preventing water extraction.

The native pasture has the least salt stored, indicating a constant loss of salt as a result of water passing through the root zone (Figure 3). Under the tree belt, there was approximately 140 t/ha of salt stored, which suggests that deep drainage has moved 40-60t/ha of salt into the ground water system. This leaching of salts and nutrients causes salinisation of ground water which then has significant effects on the plant and animal biodiversity in areas when these ground waters comes to the surface, such as in lakes or stream beds.

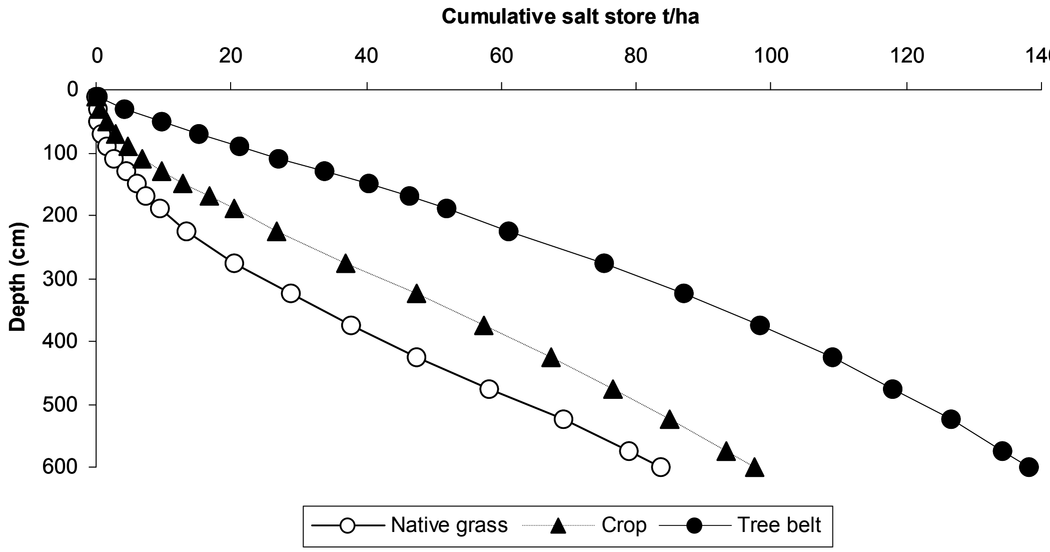

Figure 3. Cumulative salt stores under 3 land uses to a depth of 600cm.

Conclusion

The results of this study indicate that deep drainage occurs for both the native pasture and the annual cropping systems beyond 1 m, even under the arid conditions and the relatively high clay soils of the study area. These species do not utilize the entire soil profile whereas the lucerne and tree shrubs converted more of the water – both stored and incident - into biomass. These data were confirmed by the chloride profiles which indicated more water use and less deep drainage; under deep rooted perennial trees, however it is not an economically viable option for growers. On these soils, saltbush and lucerne present optons to reduce deep drainage. mainly because they are deep rooted and are able to use water during periods of high water demand.

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