Managing water resources in Australian temperate pastures

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Abstract. Increasing the amount of perennial vegetation changes the water balance at both farm and catchment scale. At the farm scale, changes to the flows of water and salt are generally as expected, though some perverse outcomes may occur, such as a shortage of surface water for stock. From a catchment perspective, downstream users are little affected by decreases in streamflow volumes, river flows appear to be more typical of pristine flows, and upstream landholders benefit from improved resilience.

Keywords: Water management, EverGraze, CATPlus.

Introduction

Currently in Australia there is a concerted effort to develop new perennial grazing systems to make agriculture more productive, adaptable, sustainable and diverse; *i.e.* resilient. Resilience is defined as the magnitude of the disturbance that a system can absorb without undergoing a regime shift (Holling 1973); or as the capacity to cope with and respond to change, such as increased climate variability or changes to terms of trade. At the farm scale, such changes may include drought or lower commodity prices. At the catchment scale, these changes may manifest as changes to water quantity or quality, reduced biodiversity or soil health.

Increasing the area of perennial pastures is key to improving resilience, as perennial pasture is better adapted to a more variable climate and provides resilience in terms of both production and environmental outcomes (Cocks 2001; Dear and Ewing 2008). For example, in recent decades, increasing the area of perennial pasture has been major tool for managing dryland salinity (van Bueren and Price 2004; Ridley and Pannell 2005). However, increasing the area of perennials within a catchment will affect the catchment water balance in terms of both water quality and quantity. These effects may be adverse if land management changes are inappropriate in space, time or structure, and composition.

One of the major issues associated with landuse change is that of equity. This arises because of the asymmetrical nature of catchments, with upstream landholders able to change the quantity, timing and quality of flows for downstream users. It is argued that to share water equitably, upstream landholders have to forgo some potential water benefits in favour of downstream users, and that these downstream users should compensate the upstream landholders, either financially or otherwise (van der Zaag 2007). This compensation to balance this asymmetry takes the form of a reciprocating flux that flows upstream, and could consist of money or be symbolic such as power or solidarity (van der Zaag 2007). In Australia, billions of dollars has been spent on research, development and on ground works to encourage upstream landholders to plant perennial vegetation (*e.g.* NAPSWQ 2000, CRC FFI 2013), so it can be argued this policy approach has been adopted. However, the effect of this investment on sustainable irrigation diversions for down stream users has been a point of contention (*e.g.* National Water Commission Interception Position Statement, NWC 2010).

Exploring both agricultural and environmental water resource outcomes at a paddock/farm scale with agricultural and environmental outcomes at a catchment scale is the focus of this paper.

This paper explores two case studies of landscape change; one at a farm scale, the other at a catchment scale and explores the interaction between landuse change (specifically increase in area of perennial pastures) and water management.

Method

Farm scale

Between 1993 and 1999, landuse changed from annual cropping to rotational grazing of perennial native pastures between tree belts on a farm near Boorowa on the south west slopes of NSW. For the purpose of this paper, the year 2000 is taken as the first year of post land use change. For a complete site description refer to Crosbie *et al.* (2007). A range of biophysical parameters have been continually measured at the site, starting between 1991 and 1996. These include monitoring of surface, ground and soil water, as well as climate.

Catchment scale

A modelling project was undertaken to determine the effect on stream flow of changing landuse at a catchment scale from annual cropping to perennial pastures, using the model CATPlus (Christie *et al*. 2011). This model climate data to catchment-scale groundwater systems and stream flows on a daily time-scale. An ensemble of crop growth and farm management models allow various types of land-use, land cover, and management strategies to be evaluated relative to their impacts on surface hydrology and landscape system dynamics.

The model simulated two catchments; the Glenelg Hopkins in western Victoria (3450 km^2), and the Tarcutta Ck (1700 km^2) in Southern NSW. A number of scenarios were used, from planting all current annual cropping to either plantation pines or perennial pastures, as well as differing level of adoption of perennial pasture based on EverGraze principles (Christie *et al*. 2011). The modelling used the rainfall record from 1900 through until 2008.

The EverGraze principles for the modelling study were based on the southern NSW/northern Victoria scenario of using a combination of fertiliser inputs and rotational grazing to increase productivity from introduced perennials while maintaining native perennials (EverGraze 2012 www.evergraze.com.au). At the same time, the current native perennial pasture base on the hills, which is not suitable to introduced perennials, was kept and improved.

Results

Farm scale

Long term median annual rainfall at Boorowa, located approximately 5 km away, is 596 mm. Median annual rainfall recorded at the site from 1996 to 2010 was 561 mm which is just over the 40th centile. Median annual rainfall during the pre change period (1995-1999) was 591 mm, 38 mm higher than the 553 mm/yr during the post-change period (2000-2010). The amount of run-off links paddock-scale land-use, soils, topography and from the site between 1996 and 1999 was 148 mm or 8.4% of the total rainfall for the period (Table 1). By comparison, total runoff between 2000 and 2010 was 129 mm, or 1.9% of the total rainfall for the period (Table 1).

Salt was exported at a rate of 59 kg/ha/yr during the pre-change phase and exported at a rate of 28 kg/ha/yr during the post change phase. The flow weighted mean salt concentration of the runoff water was 0.9 kg/m^3 pre-change and 0.8 kg/m^3 post change (Table 1).

Groundwater depth varied between 1 m and 12 m below the ground surface during the pre-change period. Rainfall strongly influenced the changes in groundwater depth during this period, the groundwater rising after rain (wet winters in 1993, 1995, 1996 and 1999) and dropping when no rain was recorded (Fig. 1). However, in the post change period, rainfall was not significantly correlated to changes groundwater levels (for a more detailed analysis see McCulloch *et al*. 2006), with watertables steadily declining until the very wet 2010-2011 years when they rose and fell quickly.

Evapotranspiration (ET) as a proportion of the water balance increased from 85% of the received rain during the pre change phase to 96% of rainfall during post change phase. Between 2006 and 2009 all rainfall was converted to ET, as no runoff or deep drainage was measured.

Table 1. Key on farm biophysical changes. Standard deviation represented by sd.

Key indices	Pre change	Post change
Runoff coefficient	8.4%	1.9%
Salt exported kg/ha	59 sd (12)	28 sd (12)
Salt conc kg/m^3	0.9 sd (0.7)	0.8 sd (1.3)

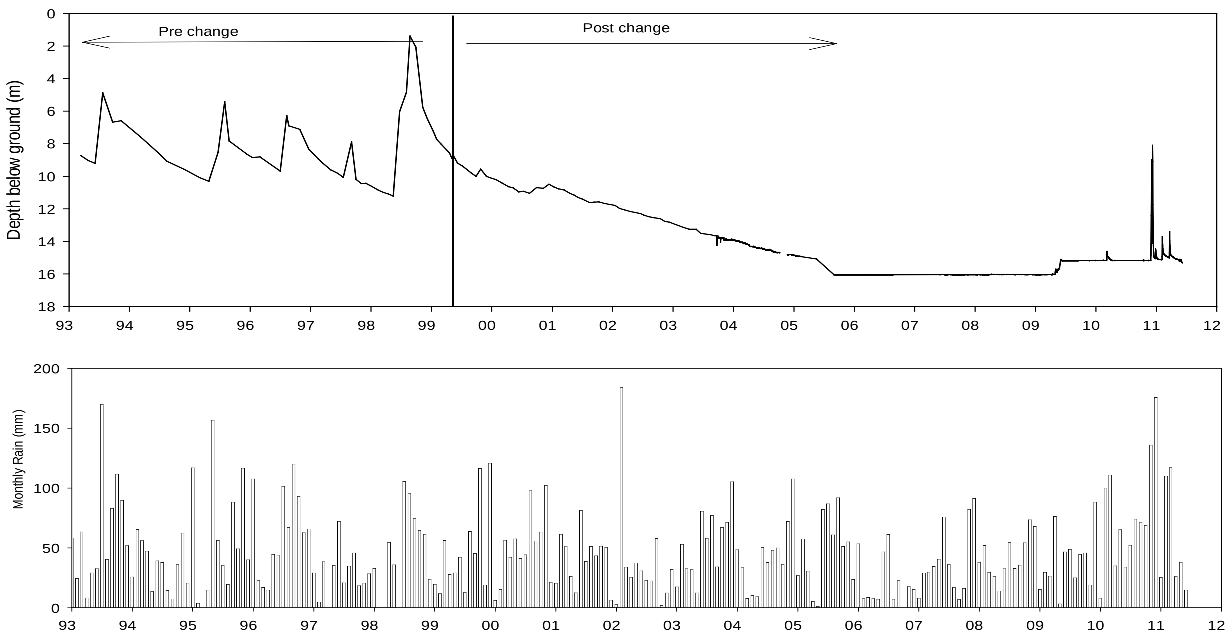

Figure 1. Groundwater elevation (m) and monthly rainfall

Catchment scale

For the entire Tarcutta catchment the CATPlus model showed a 100% EverGraze adoption rate across the entire Tarcutta catchment would reduce the long term median flow by 37% (from 86 mm/year to 54 mm/year). If the tree cover was 100%, the model showed a reduction of flows under the same rainfall regime of 65% (from 86 mm/yr to 30 mm/year). At a probable adoption rate (10%), modelled streamflow was reduced by only 3% (from 86 mm/yr to 83 mm/yr). Changes to the behaviour of modelled stream flows showed that the creek became more ephemeral as the area of perennial vegetation increased, with the volume of baseflow decreasing and the volume of quick flow (direct runoff) increasing.

Under current conditions, CATPlus showed that farm dams maintained a sufficient water volume for stock for 96% of months. With increasing EverGraze adoption, the model showed that both the area with dry dams and the period of no water in dams increased. However, only the scenario with 100% adoption of EverGraze caused dams to be dry for extended periods.

Discussion

The two case studies described here show clearly that changing landuse changes the volume, timing and quality of water flowing from farms and catchments.

The change in landuse monitored at the farm scale coincided with the "millennium drought" (SEACI 2012). The effects of this on the outcomes discussed below were minimal and are described in detail by Crosbie et al. (2007).

The change from annual cropping to perennial pasture at the farm scale decreased salt and water exports, reduced recharge and reduced saline groundwater discharge. However, the flow weighted mean salt concentration did not change significantly, suggesting that the reduction in water export was the main driver for the reduction in salt export.

The changes in streamflow at the farm scale showed that ET increased and both surface flow and deep drainage decreased. This would benefit pastures by increases to biomass, and potentially improved grazing. The decrease in deep drainage is usually a positive outcome, particularly in terms of salt mobilisation in this case the mean concentration of salt exported did not change (kg/m^3), however the mass of salt (kg/ha) halved. This decreases to surface flow again is usually a positive outcome in water quality terms, particularly reduction in the amount of salt that is washed into streams. However, reduced surface flows may be a cause for concern, as these flows are used to replenish on-farm water (dams, stock tanks) .On specific farms, localised surface water deficits would be problematic to livestock grazing enterprises if there was widespread adoption of a perennial grazing system.

The depth to watertable increased and this contributed to the reduction in runoff as more water infiltrated and was stored in the soil profile. The change from annual cropping to perennial pasture deceased recharge and, as a consequence, reduced saline discharge, also in line with other studies in temperature SE Australia (Ridley and Pannell 2005). ET increased as a proportion of rainfall and it is assumed that the pasture was exploiting the rainfall where and when it fell and that this led to increased pasture growth and hence farm productivity and profitability (Hoque and Bathgate 2008). As a consequence of the landuse change, groundwater levels were no longer correlated to rainfall (McCulloch *et al*. 2006), suggesting that the groundwater was disconnected from the surface water. However, this disconnection did not reduce the mass of salt exported per cubic metre of water.

At the catchment scale, the decrease in water exports from this landscape was considered beneficial as the amount and concentration of salt was reduced. However, when salt was not a factor in the model and all the available land was converted to EverGraze principles, the volume of streamflow decreased by 37% (from 86 mm/yr to 54 mm/yr). A more sensible figure of 10% adoption of EverGraze showed reduction from 86 mm/yr to 83 mm/yr in the volume of streamflow.

Under the realistic adoption scenario (*i.e.* 10% adoption of Evergraze) the volume of streamflow was reduced by only 3%, so the equity of water sharing remained unchanged in terms of volume. However there maybe changes to the seasonality of the stream flow and this may have larger effects on equity than simply changes to streamflow. It is apparent from the model results that a larger uptake of perennial pastures will decrease streamflow. The risk of landuse change decreasing streamflow is then dependent on effecting the change itself (adoption rates) rather than the physical change to upstream landscapes.

Public investment in landuse change has been targeted to the upper catchments to counter the physical asymmetrical nature of catchments (van der Zaag 2007). This targeting has been by investing in research, development and on ground works at the landscapes in the headwaters of the catchments. On the evidence presented in this paper there is little effect on streamflow. It can be inferred that downstream users are also little affected by this decrease in streamflow; that the flows in the rivers appear to be more typical of pristine flows; and that upstream landholders are benefiting from improved resilience.

Conclusions

Managing water involves consideration of scale. The management of water at a field scale revolves around conserving or maximising productive use of water in the root zone as well as providing surface water for stock. Management of water at a catchment scale is concerned with allocation distribution and water quality. In the light of the above examples it can be seen that increasing the perennial pasture components of the landscape can have benefits at the farm scale, including reducing the runoff and increasing the store of rainfall in the rootzone and by extension potentially increasing biomass from increases in evapotranspiration. The reduction of runoff from saline landscapes reduced salt export, but also reduced surface water availability which, at the farm scale, resulted in reduced availability of stock water in times of low rainfall.

At the catchment scale, an increase in perennial vegetation reduced overall streamflow. However, at realistic adoption rates, this was insignificant. Interestingly the increase in perennial pasture at the farm scale causes the stream to revert to more pristine conditions with an increase in the volume of direct runoff as compared to baseflow.

The equity of the catchments appear to be in balance with public investment flowing into the upper catchment areas, while water flows remain unaffected downstream. The catchment as a whole has at least maintained resilience, as upstream users have improved landscapes and downstream users have had no change to water flows.

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