Reducing deep drainage through controlled runoff management in high recharge tablelands landscape

W.I. Packer[1], **D.L. Michalk**[2], S. Brisbane[3], P.M. Dowling[2], G.D. Millar[2], W.McG. King[2], D.R. Kemp[3] and S.J. Priest[2]

CRC for Weed Management Systems
[1] Department of Land and Water Conservation, Cowra, NSW 2794.
[2] NSW Agriculture, Orange Agricultural Institute, Forest Rd, Orange, NSW 2800.
3 The University of Sydney, Faculty of Rural Management, Leeds Pde, Orange, NSW 2800.

Abstract

The Central Tablelands of NSW is a major recharge area for the Murray-Darling Basin. Tree clearing to develop native and sown pastures for livestock enterprises has increased the rate of salinisation lower in the catchment through contributions to rising ground water levels from degraded pastures. The maintenance of vigorous perennial pastures, to replace the degraded annual pastures, is seen as one means to reduce deep drainage by increasing water use during the summer period. In this paper we report some results from a large field experiment undertaken at Carcoar in the Central Tablelands of New South Wales as part of the Sustainable Grazing Systems National Experiment. At this site, the water usage of naturalised and sown perennial pastures was compared over three years (1999-2001). The results suggest a small but significant advantage of cocksfoot/phalaris pastures over naturalised pastures in reducing water losses from the root zone. However, runoff data from these pasture types indicated that the amount of ground biomass present had a much larger impact on potential losses through drainage than pasture type because infiltration was maximised when biomass exceeded 2 t DM/ha. This suggests that by increasing forage utilisation in the spring on selected paddocks located in high recharge areas, Central Tablelands producers could effectively reduce deep drainage by maximising runoff and thereby supplying good quality water to the catchment. Strategies that maintain the high perennial grass contents needed to reduce the erosion risk are discussed.

Introduction

The Central and Southern Tablelands is a major recharge area for the Murray-Darling Basin. A large proportion of the recharge area has already been cleared to develop native and sown pasture for livestock enterprises. This has resulted in rising ground water levels in the south eastern highlands that has increased salinisation on a wider scale than previously predicted (1). For example, the impact of excessive water leakage from the recharge area into the Belubula River (which is part of the Lachlan River catchment) is evident in declining water quality with the salt content exceeding the drinking water standard (EC = 800 μS/cm) for >60% of the time during 1998. This is expected to rise to 80-100% by 2020. Based on the present rate of salt increase, the water in the Belubula River will be unsuitable for irrigation by 2100.

Restoration of tree cover through reforestation is the recommended practice for recharge management and the NSW State Tree Policy, LandCare and the Trees on Farm programs are all designed to encourage both farmers and community groups to plant trees in strategic recharge areas (2). However, since it is impractical to reafforest entire recharge zones, the maintenance of perennial pastures needs to be encouraged as an alternative option for water management. Pastures dominated by perennial species fulfil two roles in water management; they efficiently utilise soil water and protect the soil surface from erosion losses.

Sown perennial grasses such as cocksfoot (*Dactylis glomerata*) and phalaris (*Phalaris aquatica*) are more efficient than annual plants (eg. annual ryegrass (*Lolium rigidum*), silver grass (*Vulpia* spp.)) at preventing leakage to ground water because they usually have deeper and more extensive root systems and longer growing seasons. Recent research has shown that a well-grown perennial grass pasture can reduce deep drainage below 180 cm by one-third to one-half compared with typical annual pastures on a duplex soil (3). Other deep-rooted pasture plants such as chicory (*Cichorium intybus*), a perennial pasture herb now recommended as a finishing pasture for prime lamb production, may prove to be as efficient as perennial grasses in the Tablelands to reduce water leakage in recharge areas.

Another significant problem with pastures dominated with annual species is that the plant cover over summer and autumn is low and results in losses of nutrients in runoff that contribute significantly to the decline in water quality in rivers and reservoirs. The main nutrients of concern are nitrogen and phosphorus (P). Nitrogen is transported attached to organic matter in sediments while P is usually attached to clays and oxides with high surface areas. Nutrient and sediment losses are significantly reduced as plant density, cover and biomass increase (4), especially perennial species that provide better protection than annuals over the summer period when high-intensity short-duration storms are most likely to occur in the Central Tablelands. However, increasing plant biomass also increases the amount of water infiltrating the soil, thereby increasing ground water recharge.

This paper aims to examine the impact of perennial grasses on water usage and surface runoff from grazed pastures and to comment on the possible role of grazing management in partitioning water to optimise production and environmental objectives. The results presented here were collected at Carcoar (33?37' S; 149?13' E) in the Cental Tablelands as part of the Sustainable Grazing Systems (SGS) National Experiment. One of the primary objectives of the Carcoar Site was to compare the relative abilities of naturalised pastures and sown pastures to control water fluxes under grazing.

Methods

The experimental site was located on a commercial property near Carcoar, about 30 km south of Orange. The site was representative of much of the Tablelands, comprising a highly variable, undulating landscape with light textured podsolic soils of low fertility (available P = 6 mg/kg) and mean pH($CaCl_2$) = 4.5. Annual rainfall for Carcoar averaged 870 mm.

This site has never been ploughed and had not been fertilised within the last 15 years. The naturalised pasture present was extremely diverse, with over 120 species being recorded. Perennial native grasses (*viz.* wallaby grass (*Austrodanthonia* spp.), kangaroo grass (*Themeda triandra*) and red grass (*Bothriochloa* spp.)) accounted for about 20% of the pasture's composition, with annual grasses (*Vulpia* spp. and *Bromus* spp.), annual legumes and broadleaf weeds (Paterson's curse (*Echium plantagineum*), thistles and flatweeds) making up the balance.

This degraded naturalised pasture (control treatment) was changed using strategic combinations of P fertiliser, lime, sod-seeded perennial grasses and annual clovers, and tactical grazing management to develop a range of pasture types. They ranged from the naturalised grassland to a highly 'improved' pasture of sown perennials (*viz.* cocksfoot and phalaris) or chicory. This resulted in four pasture systems (naturalised, naturalised + fertiliser, sown + fertiliser and chicory + fertiliser) overlaid by two levels of grazing management (*viz*. continuous and tactical) arranged in an incomplete 4 x 2 factorial (there was no unfertilised chicory) replicated 3 times. In this paper, we only compare the water regimes of the degraded naturalised pasture, that is representative of many pastures in the central Tablelands, with the tactically managed sown cocksfoot/phalaris pasture which was designed to utilise more water over summer/autumn.

Soil moisture content was measured to a depth of 1.8 m at about four weekly intervals with a calibrated neutron moisture meter at three access tubes located in each treatment plot. Soil water deficit (SWD) was calculated as the difference between field capacity (FC) and the amount of water in the profile at time of measurement. FC was defined as the water content of the soil profile when it was fully wet up. This usually occurred in late winter/early spring.

Runoff data was estimated in three standard 100 m^2 runoff plots located in each of the two contrasting treatments, *viz*. continuously grazed naturalised pasture and tactically-managed sown pasture. Each runoff plot was equipped with dataloggers that recorded rainfall, rainfall intensity and total runoff. Pasture biomass and composition were measured inside the runoff plots at 6-weekly intervals using BOTANAL procedures. Data were analysed using ANOVA, linear regression and step-wise splining routines.

Results

Effect of pasture type of quantity of water use: Over the measurement period (1999 to 2001) both pasture types exhibited some drying of the profile over summer. Sown perennial grasses consistently used more water over the late spring to mid-autumn period as indicated by peak SWD_{max}'s of 160 mm or greater (Table 1). Initially, the naturalised pasture was less efficient at drying the soil over summer, but showed a 45% increase in the SWD_{max} over time (Table 1). This was due mainly to an increase in the perennial grass content, particularly kangaroo grass that was less palatable to sheep than other perennial grasses present.

Table 1. Effect of pasture type on SWD_{max}.

Pasture type (PT)	1999	2000	2001
Degraded naturalised	114a	134a	166b
Sown tactically managed	167a	182a	181a
Significance between PT	P<0.05	P<0.05	ns

SWD_{max} within pasture types followed by the same letter are not significantly different at P<0.05.

This suggests that perennial grass content *per se* rather than species type determined water use over summer. Linear regression (Figure 1) indicated that percent perennial present explained 42% of the variability in SWD_{max}. This relationship suggests that a perennial grass content >70% is needed to achieve a SWD_{max} >170 mm prior to the winter rains in the Central Tablelands to have any significant impact on deep drainage.

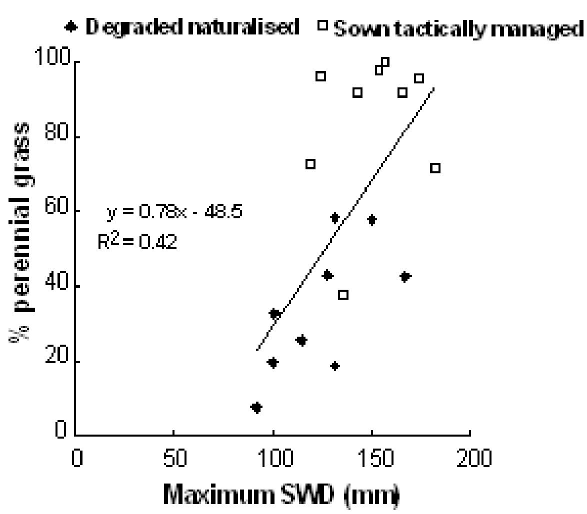

Figure. 1. Effect of perennial species on SWD_{max}.

Other results from the Carcoar site indicate that a leniently grazed cocksfoot/phalaris pasture (9.7 DSE/ha) reduced deep drainage by about 40% relative to a continuously grazed naturalised pasture (7 DSE/ha). The annual drainage losses (1-127 mm/yr) of the cocksfoot/phalaris pasture were of the same order as those reported by Ridley *et al.* (3) for a similar pasture at Rutherglen.

For Carcoar, it is unlikely that any further reductions in either deep drainage or interflow are possible given that the perennial grass content of the cocksfoot/phalaris pasture exceeded 70% over much of the 3 year experimental period. However, it may be possible to improve the water use of naturalised pastures by increasing both the amount and composition of the perennial component. This can be achieved by implementing flexible management that incorporates grazing deferment over summer combined with modest reductions in stocking rates. For example, the combination of one summer rest in 1999 and a stocking rate reduction of 20% increased the perennial grass contents of a naturalised pasture from <45% to >70% in three years. In addition to the environmental benefits of increased water usage, economic analyses show that increasing perennial grass component of pastures also has significant dollar benefits to producers when future impacts are taken into account.

Effects of pasture type on runoff: From May 1999 to December 2001, about 60 runoff events were recorded. Maximum daily runoff for each rainfall event depended more on the above-ground biomass than on pasture type (Figure 2). Most of the runoff occurred in the winter and spring when the soil profile was wettest. Our data indicated that a total biomass >2000 kg/ha consistently reduced maximum daily runoff to <2.5 mm under typical rainfall intensities (mean 1.9 mm/hr, range 0.2 – 30 mm/hr). This biomass threshold is consistent with recommendations specified in ProGraze guidelines to retain minimum biomass rates for optimal livestock performance. Unlike many other studies, there was no apparent relationship between runoff and ground cover.

Discussion

Increasing salinity is a major sustainability issue for pasture ecosystems on the Tablelands of NSW and producers are looking for new strategies to better manage the impacts of livestock grazing on water losses. These results from Carcoar indicated that improving the perennial component of all pastures is a crucial first step in addressing salinity problems. A recent survey (5) estimated that at least 40% of the Central and Southern Tablelands had pastures with some native perennial grasses, and where those grasses were present, the median content was around 25%. This means that there is plenty of scope to increase water usage by improving the proportion of perennial grasses by implementing strategic deferments of grazing and appropriate stocking rate reductions.

While these tactics would reduce deep drainage, the impact may not be large because the major soil types in the Central Tablelands are dominated by duplex soils. This means that the dense clay subsoils of these soils limit root penetration and does not allow a sufficiently large SWD to develop, irrespective of the pasture species present. With the onset of winter rains, the profiles fill by August or September, and the soils become saturated and peak drainage occurs.

Another option available to producers to reduce ground water recharge is to promote runoff by manipulating pasture biomass at critical times of the year. Figure 2 shows a strong correlation between maximum daily runoff and biomass, in which runoff is effectively controlled when biomass exceeds 2000 kg DM/ha.

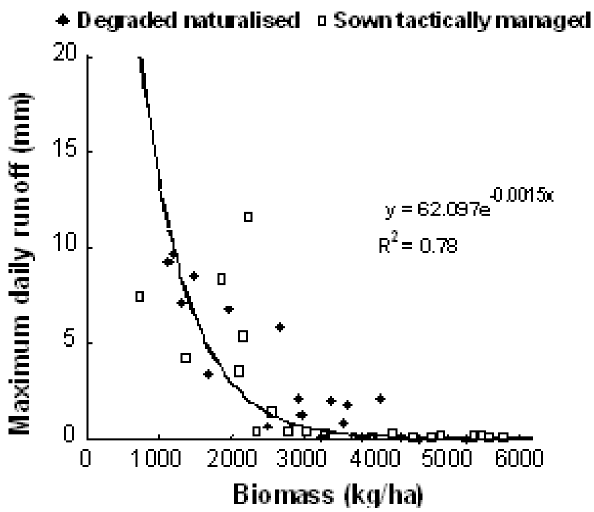

Figure 2. Relationship between maximum daily runoff (mm) and pasture biomass (kg/ha).

By increasing stocking rates on selected paddocks in high recharge areas during spring when most runoff occurs, producers could effectively reduce infiltration and at the same time supply good quality water to the river catchment. However, for this to be safe and effective a high perennial grass content (and by implication a high basal cover) would be required to provide stability to the soil surface and thereby minimise sediment and nutrient losses. Fertiliser application should also be strategically timed to minimise the P content of runoff water.

Acknowledgments

We gratefully acknowledge the financial support provided by Meat & Livestock Australia as part of the Sustainable Grazing Systems Key Program, the sterling efforts of J. Tarleton and G. Wilson in assisting with data collection, and high level of cooperation provided by W. Blazley, the owner of the Carcoar site.

References

(1) Gates, G.W.B. and Williams, R.M. 1988. Dept Water Resources NSW, Tech. Services Report 8.010.

(2) Charman, P.E.V. and Junor, R.S. 1989. BMR J. Aust. Geol. Geophysics, 11: 195-204.

(3) Ridley, A.M.,White, R.E., Simpson, R.J. and Callinan, L. 1997. Aust. J. Agric. Res., 48: 1011-1023.

(4) Johns, G.G. 1983. Aust. Rangeland J., 5: 3-12.

(5) Garden, D.L., Dowling, P.M., Eddy, D.A. and Nicol, H. 2000. Aust. J. Exp. Agric., 40: 1083-1088.