A STRATEGIC ASSESSMENT OF SUSTAINABILITY OF GRAZED PASTURE SYSTEMS IN TERMS OF THEIR WATER BALANCE

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Abstract

A simulation study was conducted to assess the likely impact on water balance, of alternative pasture and grazing management options at Hamilton, Vic., Albany, W.A. and Tamworth, N.S.W. The most important influences on drainage at these sites were the patterns of rainfall and evapotranspiration. Sites with winter-dominant rainfall (Hamilton, Albany) had a high potential for relatively large amounts of drainage (average: 100-200 mm/year), whereas at Tamworth (summer-dominant rainfall) the likelihood of drainage events was low. Shifting from annual to perennial pastures at Hamilton and Albany reduced drainage by 32-44%. ?Maintenance of vigorous pasture growth (high soil fertility) was predicted to also have incremental benefits but changes to grazing rotations and pasture rests were of no benefit. Mature woodlots at Hamilton and Albany exhibited virtually no drainage. In winter-dominant rainfall areas, changes to management of pasture systems alone will only have a relatively small impact on drainage.

Key words: Drainage, pasture management, simulation, water balance, watertables, woodlots.

In the higher rainfall areas of southern Australia (>500 mm/year), the rate of recharge to groundwater has increased where pastures, particularly annual pastures, have replaced native perennial vegetation. Estimates of the amounts of water draining past the root zone in pastures are reported to range from 20-170 mm/year where annual rainfall is 500-700 mm (7). Accessions to groundwater are resulting in dryland salinity and contributing, through the leaching of nitrate, to soil acidification. Both threaten the sustainability of grazing systems, the quality of water resources and the financial viability of agriculture.

Deep-rooted, perennial pasture species may reduce drainage in pasture systems. For instance, drainage under swards of phalaris may be 25-37% less than under annual ryegrass (7). It is also possible that management changes which result in better water-use by pastures may reduce deep drainage (eg. 2).

This paper describes a simulation study undertaken to predict the changes in water balance that might be achieved by altered pasture and grazing management at sites in southern Australia.

Materials and methods

The simulation study was undertaken for three sites proposed for experiments as part of the Sustainable Grazing Systems Key Program of the Meat Research Corporation: Vasey near Hamilton, Vic.; Manypeaks near Albany, W.A. and Connamara near Tamworth, N.S.W. Although the results are expected to be indicative, this study was exploratory in nature and undertaken with minimal input data and with limited opportunity for validation. The GrassGro decision support tool (5) was used to simulate pasture and root growth in response to grazing management on specified soils using long-term (20-25 years) meteorological records from each site. Water balances were then calculated using SWIMv2 (8), running in the APSIM (4) modelling shell. Pasture and root growth data predicted for each pasture species by GrassGro were provided as inputs to SWIMv2. The mature woodlot was assumed to have a constant leaf area index. Its root biomass was also constant and distributed exponentially to a depth of five metres. The pasture, animal, woodlot and water balance models used the same weather file to drive the simulations. Estimates of potential evapotranspiration (ET) were made using the Priestley-Taylor method (5).

Results

Water balance

Average amounts of drainage below the root zone of pastures were predicted to be in the range 100-200 mm/year at Hamilton and Albany, but were considerably lower at Tamworth (Table 1). Drainage occurred mainly in winter and early spring, coinciding with the period when rainfall exceeded potential ET.Only small amounts of drainage occurred at Tamworth irrespective of the pasture management system (data not shown). ?Use of deep-rooted perennial grasses at Hamilton and Albany was predicted to reduce drainage by 32-44% in comparison with annual pasture. However, at these sites no pasture type was capable of virtually eliminating drainage below the root zone as predicted for mature woodlots.

Various grazing and pasture management options were simulated (Table 2). Pastures grown with higher fertility levels at Hamilton were more productive, tended to use more water and have less drainage. This was not the case for higher fertility pasture at Tamworth, but drainage at this location was minimal for all pasture options. Rotational and continuous grazing regimes did not differ, and resting pastures did not reduce drainage. ?No management option reduced drainage as much as the shift from annual to perennial grasses (Table 1). Pasture comprising kikuyu was tested because its year-long growth pattern in the Albany district offered the potential for extra autumn/winter growth and greater water use. Indeed, kikuyu pasture was predicted to achieve the largest reduction in drainage of all of the pasture options tested for Albany. It was marginally better than another perennial pasture (tall fescue) because of its water-use through autumn/winter. At all sites, the year-to-year variation in the drainage term was larger than any reduction in drainage achieved by using alternative pasture species or pasture management options (eg. Fig. 1). This agrees with measurements of drainage reported from field experiments (6).

Pasture production

Three contrasting pasture growth patterns were simulated in this study. Each impacted differently on the water use by pastures. Pastures at Hamilton and Albany are based on exotic temperate species (ie. combinations of subterranean clover, annual grass, phalaris or tall fescue) which grow slowly in the autumn/winter months when rainfall and drainage are highest. The temperate perennial grasses used in these environments reduced drainage because they result in a drier soil profile prior to the autumn break. At Hamilton, where winters are cold, there may be little opportunity to change pasture growth patterns. However, at Albany winters are relatively mild and simulations revealed better growth and water use by kikuyu in autumn/winter. The native pasture grasses (red grass, wallaby grass) simulated for Tamworth, exhibited very sporadic growth and water use. Growth often occurred as short-lived flushes associated with rainfall events. However, this pattern of pasture growth was probably not the main factor contributing to the low drainage predicted for Tamworth.

Table 1. Simulated average annual water balance (mm) for different pasture types at three sites in southern Australia. Evapotranspiration (ET), drainage (D) and runoff (RO)

	Hamilton (1970-95)				Albany (1971-95)				Tamworth (1971-93)			
	Rain	ET	D	RO	Rain	ET	D	RO	Rain	ET	D	RO
Pasture type Annual[1]	639	440	195	6	693	483	206	0				
Perennial[2]		528	109	5		554	139	0	708	659	25	21
Woodlot[3]		630	13	5		694	5	0		699	0	11

[1] Averages for subterranean clover-annual grass pastures managed with high or low soil fertility at Hamilton and Albany.

[2] Averages for subterranean clover-phalaris pastures managed with high or low soil fertility at Hamilton; subterranean clover-tall fescue pasture on moderately fertile soil at Albany, and averages for subterranean clover-native grass (red grass or wallaby grass) pastures grown with high or low soil fertility at Tamworth.

[3] Mature eucalypt woodlot.

Table 2. Effects of various management options on average annual water balance (mm); evapotranspiration (ET), drainage (D) and runoff (RO)

Site	Management option	Rainfall	ET	D	RO
Hamilton	• Annual pasture (annual grass-subclover), low soil fertility	639	425	209	7
(1970-95)	• Annual pasture(annual grass-subclover), high fertility		454	181	6
	• Perennial pasture (phalaris-subclover), continuous grazing		529	108	5
	• Perennial pasture (phalaris-subclover), 4-paddock rotational grazing		529	108	5
	• Perennial pasture (phalaris-subclover), complex rotational grazing		530	107	5
	• Perennial pasture (phalaris-subclover), complex rotational grazing with pasture rested in autumn (1-30 April)		525	112	5
Albany	• Perennial pasture (tall fescue-subclover), continuous grazing (steers)	693	567	127	0
(1971-95)	• Perennial pasture (tall fescue-subclover), continuous grazing (sheep) with pasture rested in summer (29 Nov.-22 April)		541	152	0
	• Annual pasture (annual grass, subclover)		482	207	0
	• Perennial pasture (kikuyu, annual grass, subclover)		583	111	0
Tamworth	• Native pasture (wallaby grass, subclover), low fertility	708	671	16	19
(1971-93)	• Native pasture (wallaby grass, subclover), high soil fertility		661	26	20

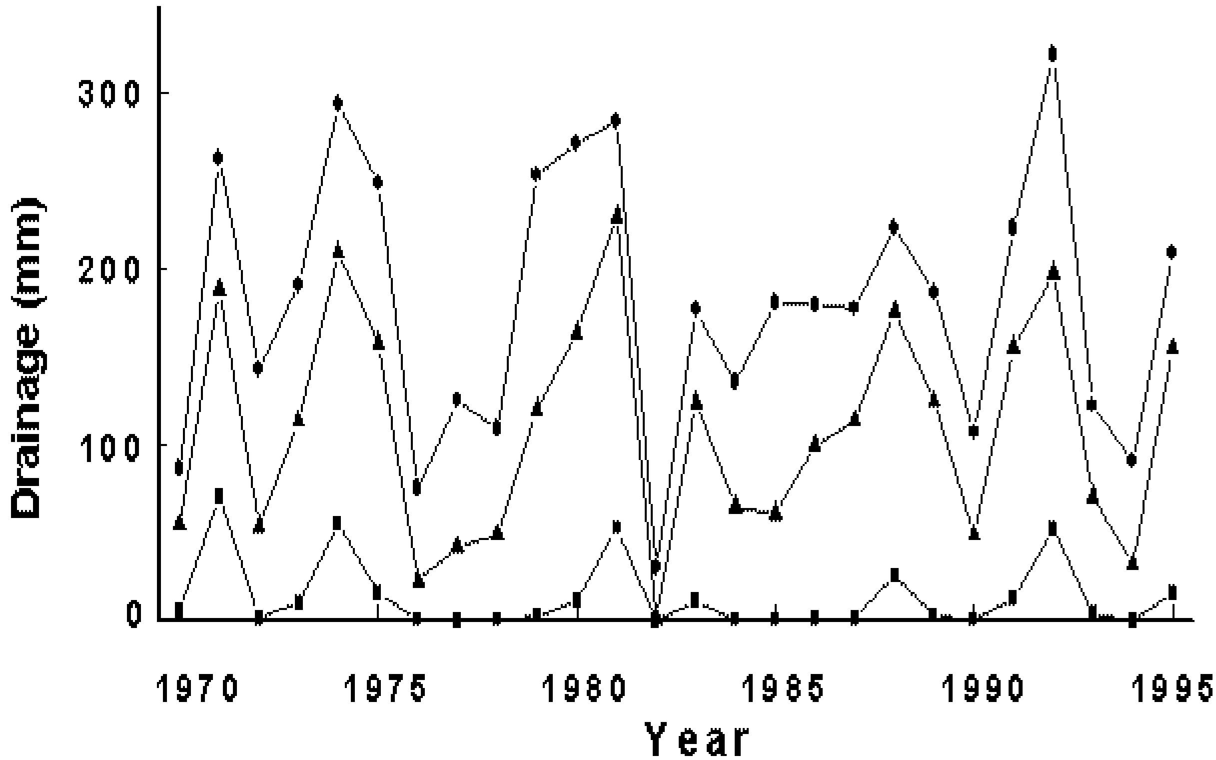

Figure 1

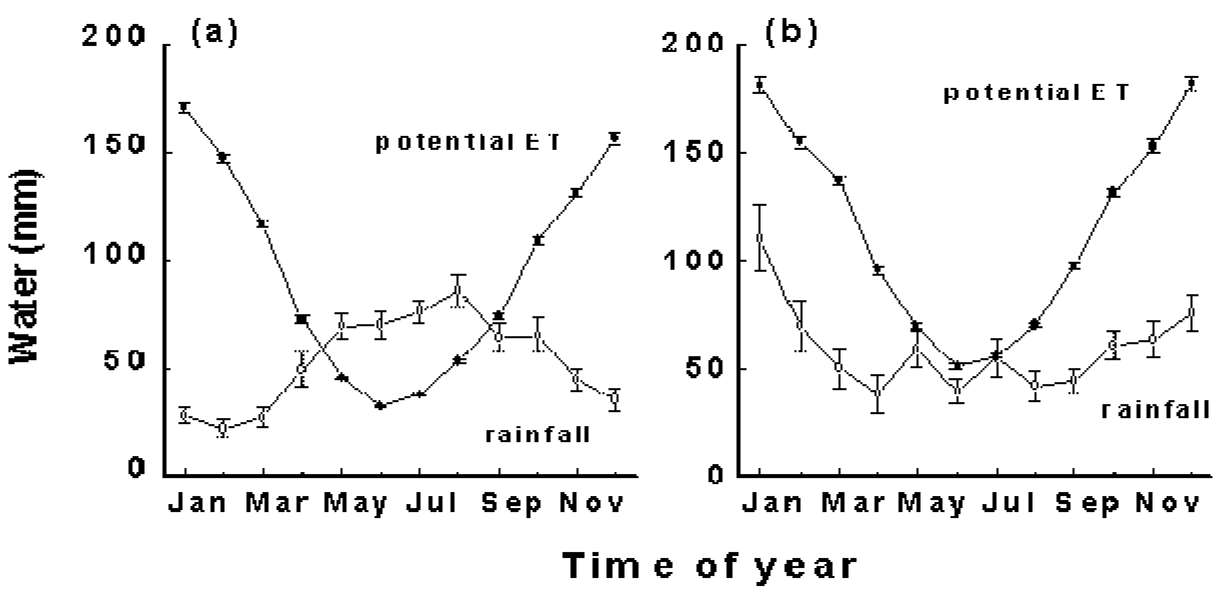

Figure 2

Discussion

Relatively large volumes of drainage water are likely to be a feature of pasture systems in winter-dominant rainfall zones of southern Australia. The simulations support the notion that good pasture management practices which promote vigorous pasture growth, and the inclusion and persistence of perennial species, will make important but incremental reductions to drainage below the root zone of pasture systems. These practices are also consistent with productive grassland manage-ment.

However, better pasture management practices will not solve the problem of excessive drainage below the root zone. Most pasture plants do not exploit soil profiles to sufficient depth to prevent drainage from occurring. ?This is illustrated by comparing the rainfall and potential ET for pasture growing at Hamilton (a site with considerable drainage; 109-195 mm/year) with that for pasture growing at Tamworth (a site with minimal drainage; ~25 mm/year) (Fig. 2). At Hamilton, there was approximate-ly 130 mm of excess rainfall which the vegetation could not use even if actual transpiration were to approach the potential ET. The only way that near zero drainage could be achieved would be for the water to run off, or for it to be stored in the root zone for use by the pasture later in the season. For drainage to be prevented in "average" years at Hamilton, we estimate (from the water-holding characteristics of the soil) that at least 1.8 m of soil would need to be dried to wilting point before the onset of autumn rain. This is a difficult target for most pasture species but indicates why a mature woodlot can achieve near zero drainage. It is likely that this is a conservative calculation because it does not allow for wetter-than-average years, it assumes there are no preferred path-ways for drainage, and that actual ET is close to potential ET.

The comparable calculation for the Tamworth site is very different. Rainfall is summer-dominant and average rainfall does not exceed potential ET in any month. Consequently, in "average" seasons pastures have the potential to use most of the rainfall, provided they have roots to sufficient depth to allow them to cope with short-term wetting and drying events. Drainage might still be expected in some wetter-than-average years, but the rainfall and ET patterns for this area are clearly more favourable for minimal drainage under pasture systems.

These results indicate that an analysis of the patterns of rainfall, ET and pasture growth, of potential rooting depth and the water-holding capacity of the root zone, could be used to identify districts which have a potentially high risk of excessive drainage under pastures. It is also clear that strategies to reduce drainage must go wider than relatively simple changes to the management of grazing systems as they offer important, but relatively small, improvements to the water balance.

Acknowledgments

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References

1. Bond, W.J., Cresswell, H.P., Simpson, R.J., Paydar, Z., Clark, S.G., Moore, A.D., Alcock, D.J., Donnelly, J.R., Freer, M., Keating, B.A., Huth, N.I. and Snow, V.O. 1997. CSIRO Land and Water, Consultancy Report 97-31.

2. Bolger, T.P., Turner, N.C. and Leach, B.J. 1993. Proc. ?XVII Int. Grassld Cong. p. 274.

3. McCown, R.L., Hammer, G.L., Hargreaves, J.N.G., Holzworth, D.P. and Freebairn, D.M. 1996. Agric. Syst. ?50, 255-271.

4. Moore, A.D., Donnelly, J.R. and Freer, M. 1997. Agric. Syst. 55, 535-582.

5. Priestley, C. and Taylor, R. J. 1972. Monthly Weather Review 100, 81-92.

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

7. Verburg, K., Ross, P.J. and Bristow, K.L. 1996. SWIMv2.1 User Manual. CSIRO Soils Divisional Report 130. CSIRO, Canberra. p. 107.