

The role of livestock in the management of dryland salinity

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Abstract. Management of dryland salinity in Australia will require changes in the design and utilisation of plant systems in agriculture. These changes will provide new opportunities for livestock agriculture. In areas already affected by salt, a range of plants can be grown from high feeding value legumes with moderate salt tolerance through to highly salt tolerant shrubs. A hectare of these plants may support between 500 and 2000 sheep grazing days per year. The type of plants that can be grown and the subsequent animal production potential depend on a range of factors that contribute to the 'salinity stress index' of a site, including soil and groundwater salinity, the extent and duration of waterlogging and inundation, the pattern and quantity of annual rainfall, soil texture and chemistry, site topography and other site parameters. Where the salinity stress index is high, plant options will usually include a halophytic shrub that accumulates salt. High salt intakes by grazing ruminants depress feed intake and production. Where high and low salt feeds are available together, ruminants will endeavour to select a diet that optimises the overall feeding value of the ingested diet.

In areas that are not yet salt affected but contribute to groundwater recharge, perennial pasture species offer an opportunity for improved water and salt management both on-farm and at the catchments. If perennial pasture systems are to be adopted on a broad scale, they will need to be more profitable than current annual systems. In the high rainfall zones in Victoria and Western Australia, integrated bioeconomic and hydrological modelling indicates that selection of perennial pasture plants to match requirements of a highly productive livestock system significantly improves farm profit and reduces groundwater recharge. In the low to medium rainfall zones, fewer perennial plant options are available. However, studies aiming to use a palette of plant species that collectively provide resilience to the environment while maintaining profitable livestock production may also lead to new options for livestock in the traditional cropping zone.

Additional keywords: environmental management, halophytes, nutritive value, perennial pastures, salt tolerance.

Introduction

Most of the dryland farming systems in southern Australia are based on the use of annual crops and pastures or degraded perennial pastures. The environmental sustainability of annual plant systems was questioned as long ago as

1924 when Wood (1924) suggested that replacement of native, perennial vegetation with annual plants was allowing penetration of fresh water into the deep aquifers and causing a rise in saline water tables. Salinity now threatens vast areas of southern Australia and extends up the Murray–Darling

Basin into Queensland. It has been hypothesised that overcoming dryland salinity will require 'landscape change on a scale equivalent to the original advance of European agriculture across Australia' (Cocks 2003). This review addresses 2 aspects of salinity in Agriculture.

- (i) The areas already affected by secondary salinity are large; in Western Australia alone the most recent estimates are that nearly 1 million ha are affected (Macfarlane *et al.* 2004). Much of this land is still capable of growing a range of salt tolerant plants and many of these have value as livestock feed. At the same time, the plants have the capacity to delay the spread of salinity and waterlogging through increased water use *in situ*, particularly in 1-dimensional groundwater systems (Barrett-Lennard *et al.* 2005).
- (ii) In the non-saline recharge areas of the landscape, poor use of water allows leakage past the root zone and raises the water table. This may be reduced by widespread use of perennials within farming systems. As with the saline areas, the most appropriate and profitable use of perennial plants in recharge areas is through grazing or, in some rainfall zones, commercial forestry.

The key to on-farm changes will be the development of options that contribute to whole farm management and increase profit.

Livestock options for saltland

Grazing saline land

The case for profitable livestock production on saline land has been, at best, inconsistent. Early research (Clarke 1982; Malcolm and Pol 1986) described the use of saltland for grazing, however, Warren and Casson (1994) were the first to make an objective assessment of animal performance on saltland improved by planting halophytic shrubs. Their conclusions were that the shrubs were low in nutritive value and that annual edible biomass production was usually below 1000 kg/ha. From these results, Bathgate and O'Connell (2001) concluded that the economics for improving saltland with halophytic shrubs alone were marginal. On less saline land that had been improved with tall wheat grass (*Thinopyrum ponticum*) and melilotus (*Melilotus alba*), Thompson *et al.* (2001) reported moderate levels of liveweight gain in 15-month-old ewes (40–90 g/day) over spring and summer. What is now clear is that the potential for profitable improvement and use of saline land is highly dependent on a range of factors that contribute to the salinity or the 'salinity stress index' of a site. This index is likely to be a function of soil and groundwater salinity (measured as electrical conductivity, EC) and also a function of the extent and duration of water logging and inundation (WL), annual rainfall, soil texture and chemistry, site topography and probably other site parameters. What is not clear is the extent to which these factors are collectively important. Although the term salinity stress index has not been used

before, the concept of more than 1 factor contributing to the salinity response has previously been described by Barrett-Lennard (2003). Other publications by the same author provide examples of interactions between salinity and soil texture (Barrett-Lennard *et al.* 2003).

In practice, production will be significantly increased through improvements on sites with a low salinity stress index whereas production may be little changed or even diminished with site improvement at the higher end of the salinity stress index (see Fig. 1 adapted from McCaskill and Bennetts 2004).

A national project (Sustainable Grazing on Saline Lands) is currently underway to quantify the benefits of improvements to saline sites across Australia (Edwards *et al.* 2005). Comprehensive site characterisation within this project will allow extrapolation of the conclusions and provide a basis for objective decisions on the benefits of broad scale revegetation.

Results to date indicate that at sites with moderate to high rainfall (>450 mm), low to moderate soil (EC_e , <20 dS/m), water salinities and winter waterlogging, pasture improvement can increase stocking rates in summer and autumn by 30–100% or by more than 150% if the improved pastures are also fertilised with phosphorus and nitrogen (Edwards *et al.* 2004; McCaskill and Pollard 2005). In the best years, these improved pastures provided more than 2000 sheep grazing days/ha.year. The improved pastures included tall wheatgrass, balansa clover (*Trifolium michelianum*), Persian clover (*Trifolium resupinatum*), strawberry clover (*Trifolium fragiferum*) and puccinellia (*Puccinellia ciliata*). The improved saline pasture in these experiments have, in some cases, been more productive than adjoining non-saline pastures and even the well adapted volunteer species (buckshorn plantain [*Plantago coronopus*]) and marine couch [*Sporobolus virginicus*] when managed appropriately have resulted in a modest weight gain in sheep at a time when they are usually losing weight.

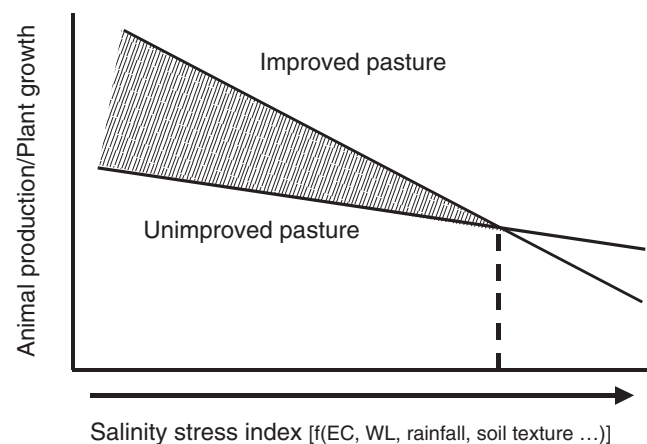


Fig. 1. Conceptual relationship between production parameters and a nominal salinity stress index being tested in the SGSL program.

At the higher end of the salinity stress index where rainfall is low (<400 mm), soil salinity is moderate to high ($EC_e > 23$ dS/m) but where waterlogging is still a risk, a shrub-based grazing system may provide ≤ 500 grazing days/ha.year (Norman *et al.* 2004b). Similar observations have been reported by others within similar environments (Morcombe *et al.* 1996). Within these salinity stress index extremes there are a range of production options. Selection and optimization of the system for any particular site is highly dependant on the characterisation of that site and is not simply a reflection of the amount of salt in the soil and water.

Although revegetation of saline sites with the best currently available plant options provides an economic return for the farm business, there are good reasons to be optimistic that there will be better opportunities in the future. Norman *et al.* (2004a) have demonstrated significant differences in productivity and nutritive value both within and between saltbush species. Selection of improved shrubs is therefore likely to improve the feeding value of these plants. Similarly, a comprehensive breeding and selection program evaluating the *Melilotus*, *Trifolium*, *Lotus* and *Medicago* genera has identified pasture legume lines with far more salt tolerance than the widely used balansa clover (M. J. Rogers, pers. comm.).

Management of high salt intakes

Grazing of the low to medium rainfall, saline valley floors of Western Australia is likely to require halophytic shrubs as a significant part of the grazing diet for the foreseeable future. The most common of these shrubs are from the *Atriplex* (saltbush) or *Maireana* (bluebush) genera. These shrub-based systems will also be applicable to saline valleys on the Eyre and York Peninsular in South Australia, in northern Victoria and western New South Wales. The plants are characterised by high salt concentrations in their leaves, which sometimes exceeds 30% on a dry matter basis (Norman *et al.* 2002). There is evidence to suggest that high-salt diets may affect all aspects of the animal production cycle, from conception and gestation, through to weaning and early growth, and finishing (National Research Council 1980). However, it may be possible to select sheep and cattle for salt tolerance. Determination of the physiological and functional implications of feeding high salt diets to grazing ruminants is necessary so that risks and benefits can be identified and production systems optimised to make the best use of saline land.

Masters *et al.* (2005) reported that beyond a concentration of 12% NaCl in the diet, growth in Merino wethers was depressed significantly. At 20% NaCl, organic matter (OM) intake was only 46% of that for a low-salt diet. At this NaCl intake, sheep maintained or lost weight whereas sheep fed the same diet with no added NaCl gained more than 150 g/day. In a companion study where sheep and cattle were compared (M. Sillence, unpublished data), feeding Angus

steers a diet containing 20% NaCl caused a reduction in OM intake similar to that seen in sheep (45% of control). However, the cattle continued to gain weight on this diet, albeit at a slower rate than cattle fed a low-salt diet (0.36 v. 1.31 kg/day). This result is significant as cattle have been considered less tolerant of high salt intakes than sheep. The effects of NaCl on organic matter digestibility (OMD) in these 2 studies are intriguing. In the study of Merino wethers by Masters *et al.* (2005), adding 20% NaCl to the diet decreased OMD from 59.5 to 54.5%. This may be a consequence of the limited tolerance of some of the rumen microbial population to high concentrations of NaCl (D. Mayberry, unpublished data) or may be related to the increased rate of digesta flow caused by increased intake of water with high NaCl diets (Hemsley *et al.* 1975). In the cattle study, the same depression in OMD was not apparent.

From a practical point of view, even on highly saline sites, grazing ruminants will have a choice of plants from which to select a diet. These plants will vary in salt concentration and ion composition, digestible energy and crude protein. Thomas *et al.* (2006) have recently shown that when sheep are given a choice of diets with a range of NaCl and energy concentrations, the availability of a low NaCl alternative will usually allow the animals to select a mixed diet that will increase intake and growth. Given the choice, sheep were able to combine high- and low-NaCl feeds to improve the overall quality of their diet. Interestingly, however, when the OMD of the low NaCl alternative declined to <55%, the sheep consumed the high NaCl diet almost exclusively (90% of total intake). This is consistent with field observations that have shown performance is improved if grain is provided as a supplement to sheep grazing saltbush but not when a low quality straw supplement is used (Norman *et al.* 2004a). These observations need to be considered in the design of saltland pasture systems for ruminants, and in the selection and use of supplements to optimise production.

The experiments described above focus on the consequences of high salt intakes on young growing sheep. Saltland pastures are usually grazed in autumn and early winter to fill the feed gap. This time also corresponds with early to mid pregnancy in the ewe flock. Grazing saltland with ewes has some tactical benefits in the management of farm feed resources. The nutrient requirements of the ewe are only increased marginally in early to mid pregnancy, so a maintenance feeding regime, such as that observed with shrub-based saltland pastures, may be appropriate. Peirce (1968) reported some depression in reproductive performance in ewes provided with saline drinking water; however, in recent studies (S. Digby, unpublished data), no detrimental effects were observed on blood pressure, lambing rate or lactation when a diet containing 15% NaCl was fed to ewes throughout pregnancy. Although pregnancy was unaffected by this treatment, there was evidence that high NaCl during pregnancy has long term consequences

in the offspring, with the lambs post-weaning showing different patterns of water consumption, urine output, plasma aldosterone concentration and plasma vasopressin when given an acute oral NaCl challenge.

Decreasing groundwater recharge in non-saline areas

Profitable use of saline land is only 1 approach to the use of livestock in the control of dryland salinity. There is also a need to reduce markedly deep drainage in the non-saline recharge part of the landscape.

Options for livestock production from perennials in the high rainfall zone

The use of perennial species that use more water than annuals is 1 of the options available in the management of water on-farm and within catchments in the high rainfall zone (550 mm/year) (Ridley and Pannell 2005). The challenge is to achieve adoption of perennial farming systems on sufficient scale to influence water management and salinity without imposing a major economic and social burden on the wider community (Stoneham *et al.* 2003). New perennial based animal grazing systems that achieve significant reductions in recharge over annual systems and increase profitability above current cropping and animal enterprises are needed.

An innovative approach to the development of new profitable farming systems that facilitate land use change in the high rainfall zone has been initiated in the 'EverGraze – More Livestock from Perennials' project. The project aims to develop new perennial pasture and livestock systems that will increase farm profit by 50% and simultaneously reduce groundwater recharge by 50%. In the initial phases of the project, integrated bioeconomic and hydrological modelling (Sanford and Young 2005) has been used. Information was gathered from innovative farmers and researchers in 2 study catchments (Albany Eastern Hinterland, WA, and Glenelg Hopkins, Vic.). In particular, the potential for including more or different perennial species was explored. For the 2 catchments, a hypothetical (typical) farm was designed at the biophysical level. This included climate,

soil types (texture and depth to B horizon) and farm size (Table 1). MIDAS (Morrison *et al.* 1986) and the Catchment Assessment Tool (CAT) (Beverly *et al.* 2005) were then used to analyse aspects of the farms to ascertain which farming systems are most likely to increase profit and reduce recharge. The models were linked via an exchange of pasture curves and paddock management protocols, the new options generated influenced both the amount and location of perennials on the farm (Table 1).

Optimum strategies for farms in the 2 study catchments are provided in Tables 2 and 3. In the Albany Eastern Hinterlands, the optimum management for the current specialist wool producer with only annual pastures carried 8.1 dry sheep equivalents (dse)/ha and used 18.5 kg of supplement per dse to a flock with 43% ewes and 34% wethers. Including the options of kikuyu and lucerne (improved system Table 2) substantially increased profit, with the optimum system predicted to be 45% kikuyu, no lucerne and 25% annual pastures with a farm stocking rate of 10.7 dse/winter grazed ha. Including the option of growing tall fescue in the future farming system reduced the area of both annual pasture and kikuyu. The greater profitability of the tall fescue was driven by its high growth rates during winter and spring with only a small reduction in quality during summer and autumn. The total area of perennials selected in the future farming system increased from 47 to 67%. Leakage below the root zone decreased by at least 45% (21 mm) when the current pasture system was replaced with any of the perennial systems. Implementation of the future system provided a further small decrease in recharge.

The meat Merino enterprise was more profitable than the specialist wool flock for each of the farm systems; however, the difference was greatest for the higher production future system. This indicates that high quality perennials are most profitably utilised for meat production rather than wool.

In the Glenelg Hopkins catchment, the optimum management identified by modelling for the current system (Table 3) with moderately productive perennial ryegrass or

Table 1. Description and area of the hypothetical farm in the study catchments

Ann, annual pasture: subterranean clover-based annual pasture with volunteer grasses and herbs; Luc^A, lucerne: a monoculture of lucerne grown in rotation with crops; Kik, kikuyu: a mixture of kikuyu and subterranean clover; Fes, tall fescue: a mixture of summer active temperate perennial grass and subterranean clover; PRG/annuals, perennial ryegrass: a mixture of sown perennial ryegrass and subterranean clover but with about 50% annual grasses; High PRG, perennial ryegrass: a mixture of highly productive perennial ryegrass and subterranean clover with high fertiliser, <20% annual grasses; Luc^B, lucerne: a monoculture of lucerne

Study catchment	Land management unit	Area (ha)	Farming systems		
			Current	Improved	Future
Albany Eastern Hinterland	Deep sands	760	Annuals	Ann, Luc ^A , Kik	Ann, Luc ^A , Kik, Fes
	Waterlogging prone duplex	260	Annuals	Ann, Kik	Ann, Kik, Fes
	Medium depth and plain duplex	980	Annuals	Ann, Luc ^A	Ann, Luc ^A , Fes
Glenelg Hopkins	Ridges	200	PRG/annuals	High PRG	Luc ^B
	Mid slopes	600	PRG/annuals	High PRG	High PRG
	Flats	200	PRG/annuals	High PRG	Fes

Table 2. Production and management parameters for the improved pasture and livestock systems in the Albany Eastern Hinterland

	Farm system			Meat Merino ^B Future
	Current	Merino flock ^A Improved	Future	
Profit (\$/ha.year)	10	40	43	82
Stocking rate (dse/WG ha)	8.1	10.7	10.1	12.0
Supplementary feed (kg/dse)	18.5	8.3	6.9	8.4
Flock structure (% ewes)	43	45	72	87
Weaning (%)	87	92	92	92
Crop (% of farm)	30	30	30	30
Annual pasture (% of farm)	70	25	19	3
Kikuyu (% of farm)	0	45	16	21
Lucerne (% of farm)	0	0	0	0
Fescue (% of farm)	0	0	35	46
Pasture growth (t/ha)	6.6	7.0	7.2	7.5
Pasture utilisation (%)	35	46	47	50
Wool income (\$/ha)	148	193	163	189
Sheep sales (\$/ha)	42	60	95	189
Leakage below the root zone (mm/year)	67	46	42	45

^A Stocking rate (dse/WG ha) assumes ewes are 1.5 dse/animal and dry sheep 1 dse/animal. WG, winter grazed.

^B Surplus ewes not needed to maintain the flock are mated to a terminal sire.

Table 3. Production and management parameters for the improved pasture and livestock systems in the Glenelg Hopkins catchment

	Farm system			Meat Merino ^B Future triple
	Current	Merino flock ^A Improved High PRG	Future triple ^C	
Profit (\$/ha.year)	100	263	226	397
Stocking rate (dse/WG ha)	12.9	21.6	20.1	22.7
Supplementary feeding (kg/dse)	30	39	39	52
Flock structure (% ewes)	52	52	52	85
Weaning (%)	71	71	71	122
Perennial ryegrass (% of farm)	100	100	60	60
Lucerne (% of farm)	0	0	20	20
Fescue (% of farm)	0	0	20	20
Pasture growth (t/ha)	9.0	12.4	11.8	13.1
Pasture utilisation (%)	52	61	59	59
Wool income (\$/ha)	451	757	705	529
Sheep sales (\$/ha)	69	118	108	458
Leakage below the root zone (mm/year)	130	121	98	98

^A Stocking rate (dse/WG ha) assumes ewes are 1.5 dse/animal and dry sheep 1 dse/animal. WG, winter grazed.

^B Surplus ewes not needed to maintain the flock are mated to a terminal sire.

^C Future triple: tall fescue on flat, perennial ryegrass on the mid slopes and lucerne on the ridges.

annual clover with grass pastures carried 12.9 dse/ha and used 30 kg of supplement per dse to a flock with 52% ewes and 24% wethers. This system generated a net profit of A\$100/ha. Upgrading the pasture to highly productive perennial ryegrass increased profit by \$163/ha. This was achieved by increasing stocking rate to 24 dse/ha and increasing supplementary feeding to 39 kg/dse. The triple pasture system (tall fescue on the flats, perennial ryegrass

the mid slopes and lucerne on the ridge) was not as profitable as the improved (highly productive perennial ryegrass) but still generated \$226/ha or \$126/ha more than the current pasture. The stocking rate was 22.3 dse/ha and the level of supplementary feeding was unchanged at 39 kg/dse. Switching to the meat Merino production system with a focus on meat production and with surplus ewes mated to a terminal sire increased profit by \$72/ha, \$146/ha and

\$171/ha in the current ryegrass, the improved ryegrass and the triple systems, respectively. The results for this comparison are shown in Table 3 and indicate that to get the most out of the triple pasture system, the animal system needs to be responsive to improved pasture quality, and summer and autumn production. This is most likely to occur in a meat or wool system with high fertility ewes. Leakage was highest under the current pasture system at 130 mm/year. The high production perennial ryegrass reduced leakage by 9 mm/year. The triple pasture system with 20% of the farm under lucerne and 20% under tall fescue reduced leakage by 32 mm compared with the current system.

In summary, modelling has indicated that in high rainfall landscapes, there are several livestock-based farming systems with the potential to deliver significant profit and hydrological improvements. In both study catchments, meat production systems provide the greatest opportunity to improve profitability from summer-active perennial pastures. Profits were significantly influenced by weaning rates and lamb growth, indicating that research and management to increase multiple ovulations, lamb survival (using nutrition and shelter) and the provision of adequate nutrition to allow lamb growth of 200 g/day from birth to weaning are priorities. Also in these catchments predicted groundwater recharge was reduced by 9–32 mm/year by the increased use of perennial pastures.

Potential use of shrubs in the feed base of crop–livestock zones

The crop–livestock zone (300–600 mm annual rainfall; Ewing and Flugge 2004), covers 35 million ha of southern Australia. Most of Australia's dryland salinity falls within this broad land class. It is also the region with the fewest options to increase the proportion of the landscape sown to perennials (Lefroy *et al.* 2005). Lucerne is an option in some areas; however, overall new strategies are required to overcome this impasse. The main reasons for this void are (i) a historical focus of improvement of annual pasture species in southern Australia; (ii) some exotic species with potential application have been excluded for their weed risk (Rogers *et al.* 2005), an issue that will become even more stringent with tighter AQIS restrictions on plant imports; and (iii) many shrub species including native and naturalised species (Lefroy 2002) and perennial legumes (Dear *et al.* 2003) have been rejected owing to low biomass productivity, high costs of establishment or the presence of anti-nutritional factors.

Annual water use by plants is often less than annual rainfall in the crop–livestock zones because the plant species that currently dominate are mostly annual legumes and grasses in south western Australia (Doyle *et al.* 1996; Puckridge and French 1983; Purser 1980) or a mixture of annual and perennial species in south-eastern Australia (e.g. Michalk

et al. 2003). Consequently, even in these low rainfall areas, recharge of the water table has increased, leading to dryland salinity. A second problem from a production point of view is that the feeding value of pastures (a function of nutritive value and the supply of accessible, palatable feed) is highly variable across seasons and is maximal for only a short time each year (in spring). This, in turn, is reflected in distinctly seasonal patterns of animal production and the use of expensive feed supplements over summer and autumn.

Correcting the uneven seasonal distribution of green feed is not straight forward because the summer and autumn drought in much of the crop–livestock zone means that shallow rooted plant species do not survive over summer and autumn and, indeed, many perennial grass species are inactive over summer as a survival strategy for this type of environment. Livestock production within the constraint of Australia's variable climate would be enhanced by using (and managing) a palette of plant species that collectively provide resilience to the environmental and climatic constraints while also maintaining profitable levels of animal production. A strategy that may achieve these twin ambitions is one that combines deep-rooted shrub species with annual or perennial herbaceous species that provide nutritional and seasonal complementarity to the shrubs.

There are few shrub species that have been widely adopted in southern Australia, with saltbush and tagasaste being the 2 exceptions. Research to test different strategies of utilisation with these species, indicates that animal performance can be substantially improved if they are fed in combination with supplements (Table 4). Less work has addressed the potential to use mixtures of plant species, rather than relatively expensive feed supplements, to provide nutritional complementarity or to optimise rumen function. The spatial allocation of such mixtures is likely to be important (Dumont *et al.* 2000) because it may enhance the capacity of animals to select a balanced diet. For example, sheep had a higher rate of liveweight gain when offered alternating strips of ryegrass and clover compared with a standard ryegrass and clover mixture; however, they did still eat a combination of plant species rather than selecting 1 species exclusively over the other (Cosgrove *et al.* 2001).

A relatively unexplored opportunity is the potential value of native shrub species as part of a mixture of forage species. Native species, having evolved in Australia, offer the potential advantage of exhibiting adaptability or resilience to the environment of southern Australia. Their use offers additional opportunities to maintain or improve site and landscape biodiversity. Native shrubs have not undergone coordinated screening, selection or plant breeding to improve nutritive value or productivity, yet within-species variation is known to exist. George (N. George, unpublished data) has found significant differences in nutritive value of *Acacia saligna* populations, with some of this variation being associated with genetic variation in the species.

Table 4. Indicative nutritive value of some shrub species, and indicative levels of animal production in autumn in southern Australia for animals on tagasaste or saltbush, with and without supplementationDMD, dry matter digestibility estimated *in vitro*; CP, crude protein; NDF, neutral detergent fibre; n.a., not available

	Feed on offer (kg DM/ha)	DMD (%)	CP (%)	NDF (%)	Autumn LW gain (kg/animal.day)
Tagasaste (cattle) ^A	400–500	68	19	35	0
Tagasaste + 1.8 – 3.4 kg lupins/animal.day (cattle) ^A	—	—	—	—	0.85–0.93
Saltbush (sheep) ^B	170	72	11	30	0
Saltbush + 250 g barley/animal.day (sheep) ^B	—	—	—	—	60
Alternative native species					
<i>Acacia saligna</i> ^C	n.a.	49–56	11–17	n.a.	n.a.
<i>Eremphila longifolia</i> ^D	n.a.	75	13	n.a.	n.a.
<i>Indigofera australis</i> ^D	n.a.	70	21	n.a.	n.a.
<i>Maireana rohrlichii</i> ^D	n.a.	65	27	n.a.	n.a.
<i>Rhagodia spinescens</i> ^D	n.a.	67	21	n.a.	n.a.
<i>Santalum acuminatum</i> ^D	n.a.	82	5	n.a.	n.a.

^AData from G. Tudor (unpublished data).^BData from Franklin-McEvoy (2002).^CData from N. George (unpublished data).^DData from Bennell *et al.* (2004).

Similar variation has been reported in *Atriplex amnicola* (river saltbush) grown under controlled conditions with either saline or non-saline irrigation water (Tiong 2005). Other native shrub species have not undergone such broad testing, but preliminary results on nutritive value (Bennell *et al.* 2004) indicate a number of species with promising nutritive traits (Table 4). There is anecdotal experience to suggest many of these species are palatable to livestock (Bennell *et al.* 2004), but to date there has been a limited assessment of their productivity and quality over time. Even with native shrubs, however, there is a weed risk and this is already being seen in South Australia with *Acacia saligna* introduced from Western Australia (Maslin and McDonald 2004).

From an animal production point of view, shrubs can provide the following benefits.

- (i) Edible green feed out of season. If active during summer (with a C₄ photosynthetic pathway), shrubs can provide green biomass out-of-season (summer and autumn) and thus broaden seasonal feed distribution. Where the shrub roots can access the water table, they will be less reliant on summer rainfall events to be productive at this time of year. Green feed in summer and autumn can have an economic value of up to 10 times that of equivalent quality feed in spring (Morrison and Bathgate 1990).
- (ii) Shade, shelter and ground cover. The advantages of an enhanced thermal environment for grazing animals are often undervalued. A deviation of 5°C outside the thermoneutral zone can increase the maintenance requirement by about 25%. For example, this increase

in maintenance requirement can be experienced, even at zero wind speed, with a drop in temperature from 28 to 23°C for newborn lambs or from 31 to 26°C in shorn adult sheep (McDonald *et al.* 2002). This will reduce the efficiency of converting feed into animal product and, if the supply of high quality feed is limited, may also reduce the level of production.

- (iii) Plant bioactives. Strategies to capitalise on beneficial plant compounds in grazing systems are largely unquantified and rarely considered. However, with growing societal pressures to reduce chemical inputs and improve animal welfare, this is an area of research opportunity. Benefits may arise through manipulation of the rumen microbial environment or exploiting the effects of plant compounds (such as condensed tannins) on gastrointestinal internal parasites (Ramírez-Restrepo *et al.* 2004).

However, shrubs as a component of the feed base have the following main limitations.

- (i) Low productivity. The successful use of shrubs in a grazing system will depend on how they are matched with herbaceous pasture species to provide sufficient high-quality feed to meet production targets.
- (ii) Incomplete provision of nutrients. This raises the need to consider the strategic use of supplements. For example, a relatively small amount of grain supplementation (250 g barley grain/animal.day) to a saltbush-based pasture in South Australia allowed sheep to gain weight over autumn, and wool growth rate was double that normally achieved with sheep grazing dry residue from annual pastures (Franklin-McEvoy 2002).

(iii) Woody components and leaf material inaccessible to livestock. Most shrubs have a high proportion of woody biomass that is either inedible or poorly digested (Lefroy 2002). This problem is exacerbated when areas planted to shrubs are not adequately managed (a fence off and forget approach). However, if a shrub-based system is combined with grazing management strategies, these limitations may be minimised (Wilson 1994).

An opportunity exists to enhance the use of plant mixtures to meet the growing pressures to achieve high productivity while also improving environmental outcomes. The incorporation of shrubs into a plant mixture warrants special consideration in the low–medium rainfall zones where other plant options to meet these dual objectives are limited.

Conclusions

Livestock offer practical options for the use of saline land and the expansion of perennial plants within the non-saline, recharge areas in the landscape. In many cases these are profitable in their own right, meaning that broad scale landscape change is a profitable farming alternative. This is particularly the case with saline land with a low salinity stress index in the high rainfall (550–750 mm) farming zones. The low and medium rainfall zones offer more challenges, with low productivity from salt tolerant plants and fewer perennial pasture or shrub options. Even in these areas, however, there is reason for some optimism with multi-disciplinary research teams investigating the effects of paddock scale changes on farming and landscape scale economics, hydrology and biodiversity.

Integrated bioeconomic and hydrological modelling indicates that it is possible to achieve significant reductions in recharge with large increases in profit with improved farming systems based on perennial pasture plants. The common attributes of these farming systems include large parts of the farm sown to summer active perennials (tall fescue, lucerne and kikuyu) combined with a sheep system with high weaning rates, lambing in late winter and spring, and producing both meat and wool. On-ground studies are required to determine the best mix of sheep genetics, management and pastures to optimise profits and water use in the target areas.

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