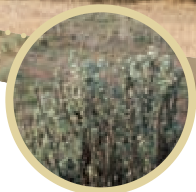
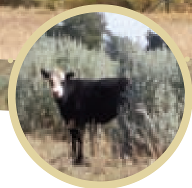
Perennial forage shrubs providing profitable and sustainable grazing

Key practical findings from the *Enrich* project





FUTURE FARM
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Contents

Enrich project contributors include:

Future Farm Industries CRC; CRC Australia; mla Meat & Livestock Australia; CSIRO; The University of Western Australia — Achieve International Excellence; Department of Agriculture and Food, Government of Western Australia; NSW Government Industry & Investment; SARDI Research and Development; Joint Venture Agroforestry Program (Rural Industries Research & Development Corporation, Forest & Wood Products Research & Development Corporation, Land & Water Australia, Murray-Darling Basin Commission); awi Australian Wool Innovation Limited

Introduction and overview

This booklet is designed to help farmer groups, natural resource management (NRM) or catchment groups, individual farmers and advisers to see the benefits of incorporating forage shrubs into mixed farming systems, particularly, but not exclusively, for areas where other perennial plant options are limited. In addition, information is provided to help with the decisions on what shrub species to plant and the key principles of grazing management.

The information has mostly been obtained from the *Enrich* research project that started during 2004 to explore the potential of Australian native shrub species for grazing systems. Researchers from across Australia have been assessing the traits of a large number of shrub species, both in the field and in the laboratory, and have been testing different grazing management approaches with a particular focus on grazing diverse mixtures of plant species.

Livestock, with correct management, can cope and perform well with diverse plant mixtures, selecting a wide range of plants in their diet.

The proposition presented here is that, for a 'typical' farm in the low–medium rainfall crop-livestock zones of southern Australia, the inclusion of perennial forage shrubs at about 10–20 per cent of farm area can increase whole-farm profit by 15–20 per cent. This is achieved by reduced supplementary feeding during the summer/autumn feed gap and, importantly, by deferring the grazing of other parts of the farm at the break-of-season, allowing better management and more pasture to be grown elsewhere.

In most cases, perennial shrubs complement rather than compete with cropping. Also, the perennial shrubs do not compete with pasture, but are an addition to the existing feed base.

Perennial Australian shrubs, grown in a mixture, can provide out-of-season feed, contribute to protein and mineral nutrition, improve the efficiency of livestock digestion, help control gut parasites, and provide shelter and shade. And there is a suite of other NRM benefits, such as controlling dryland salinity, wind erosion and improving biodiversity.

1. The value of forage shrubs to farming systems — whole economics

Including perennial forage shrubs can increase whole-farm profit in the order of 20 per cent, and provides multiple environmental benefits. The farm profit 'response curve' shows a steady increase as the proportion of shrubs increases up to 10–20 per cent of a so-called typical mixed-crop–livestock farm (see Figure 1). After the point of profit maximisation including more shrubs starts to reduce whole-farm profit, but it is not until 30–40 per cent of the farm area is allocated to perennial shrubs that whole-farm profit drops below that achieved with no shrubs at all, allowing 'room to move' when planning shrub establishment.

Establishing perennial shrubs for livestock forage is a medium–long-term venture. The number and type of shrubs must make a positive contribution to the farming system, both economically and environmentally. There must be a plan to use them every year, not just when things get tough. A small patch of shrubs will not provide enough grazing days to really boost profitability. Too many shrubs will carry an opportunity cost by restricting the options for other enterprises.

The bio-economic analysis here was carried out with MIDAS, a model that selects a farm strategy that maximises farm profit in the medium term. It takes into account economic trade-offs of adding new farm options into the system.

The information here is based on a 'typical' central wheatbelt farm in Western Australia:

- 2000 ha crop/livestock farm.
- 350 mm average annual rainfall, with 80 per cent in a short growing season.
- Mixed soil types, with eight 'land management units' represented in the model.

There is particular potential for shrubs to boost economic returns in marginal landscapes, such as drier regions or in areas with low-fertility soils. It is important to consider the different land classes, or soil types, on a farm, as this directly determines the potential of other enterprises (for example, cropping).

In Figure 1, for a farm with 7 per cent of its area as marginal, the optimal area to allocate to forage shrubs was 10–20 per cent.This increases to 30 per cent for a farm with 15 per cent of its area classed as marginal. Interestingly, where cropping is not a dominant farm enterprise, some producers establish shrubs on better country, rather than their poorer soils, to more fully realise the growth potential of the shrubs for forage.

It is also important to know that perennial shrubs will boost whole-farm profit even when grain prices increase. Economic analysis reveals that grain prices have a predictably large effect on farm profit, yet optimisation of whole-farm profit is always achieved with perennial forage shrubs. This is still the case in years with high grain prices. And critically, the optimal area of a farm established with shrubs does not change with grain prices, (see Figure 2), because the shrubs are best placed in marginal cropping areas (i.e. where cropping input costs are higher or grain yields are lower).

FIGURE 1. Effect of shrub area on whole-farm profit according to proportion of marginal soils

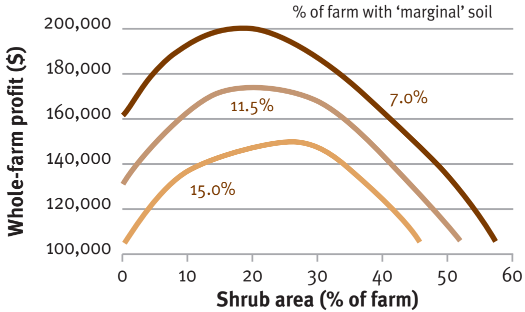
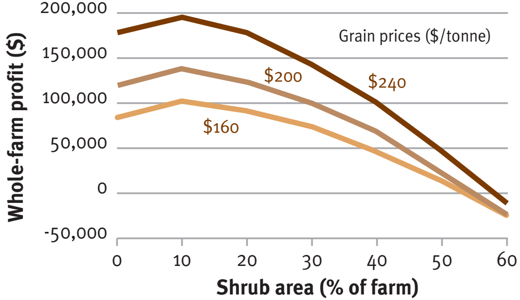
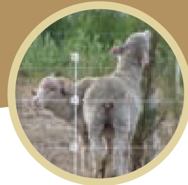


FIGURE 2. Impact of area established with shrubs on whole-farm profit with fluctuating grain prices





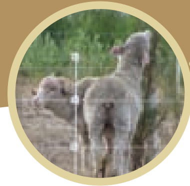
2. The value of forage shrubs to farming systems — how do forage shrubs boost whole-farm profit?

The first way forage shrubs boost whole-farm profit is by reducing the amount of supplementary feed required. Supplementary feeding has a direct cost, can be expensive, and generally has an indirect labour cost. Economic modelling reveals that in a 'typical central wheatbelt' farm, forage shrubs at about 10 per cent of the farm area can boost farm profit by 15–20 per cent. Half this profit arises because of a reduction in the need for supplementary feed (supplementary feed costs dropped from about $13/ha to $5/ha). This has recently been demonstrated on a 10 ha research site established with a mixture of forage shrubs, where sheep at 10 head/ha gained weight and condition score over six weeks during autumn without any supplementary feeding. The shrubs were 3.5 years old at the time, and excellent ground cover in the inter-row spaces remained at the end of the six-week grazing period.

Accounting for just more than half of the profit increase, the second important key way forage shrubs boost whole-farm profit is by allowing producers to defer grazing of annual pastures during early winter. Grazing forage shrubs at this time enables better winter pasture

establishment and, in turn, allows a higher stocking rate (typically in the order of 1 DSE/ha on an annual whole-farm basis).

These points highlight why it is important to evaluate the economic potential of forage shrubs on a *whole-farm basis*. That is, consider more than just the gross margins for the paddock/s in which the shrubs are located, and think about the impact on the whole-farm system and profitability.



There are other benefits to farm profitability that are not yet captured by this economic analysis. These include:

- Improved flexibility of labour at sowing by having animals grazing shrub-based systems at the break-of-season.
- Improved ground cover and reduced wind erosion by including deep-rooted species that provide persistent cover and act as windbreaks.
- A management tool to deal with climate variability and climate change, because of the propensity for deep-rooted perennial shrubs to withstand extended dry periods and respond to out-of-season rainfall events.
- Management or control of dryland salinity by deep-rooted perennial shrubs, helping achieve hydrologic balance.
- Biodiversity benefits are expected through the addition of structural (form) and functional (different types of plant groups) complexity of shrub plantings.
- Potential improvements in carbon balance.
- The potential for nutrients to be brought back to the surface from lower depths and made available to other plants.
- Provision of shade and shelter (see Section 13).
- Reductions in the intensity of greenhouse gas emissions from livestock (see Section 10).
- Improvements in animal productivity by increasing feed intake or improving gut function (see Section 7).

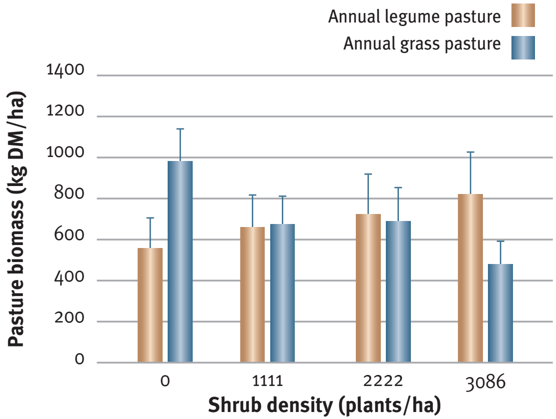
3. Forage shrubs should be part of a mixture

Forage shrubs, especially Australian native species, are not noted for their production of high-quality, edible biomass. But they are noted for their suitability to our climate and resilience to tough conditions, including extended dry periods. This means we are interested in adding forage shrubs to the feedbase, not replacing existing components.

Even with shrubs, the bulk of the biomass that fuels animal production will still come from a productive inter-row pasture, or shrub understorey. We have demonstrated the growth of annual pasture legumes is not compromised when grown alongside shrubs (see Figure 3) and in fact, in one study, the nitrogen and potassium content of the annual legume pasture increased when grown as an understorey to shrubs. Therefore, incorporating shrubs in a legume-based system is a true addition to the forage base, rather than a substitution. While annual grass production is reduced with high shrub density, at moderate shrub density (for example, <1000 shrubs/ha) the loss of grass biomass is compensated by the increase in shrub edible biomass.

Research indicates that shrubs may typically constitute one-quarter to one-third of the dry matter intake of sheep. Saltbush studies during autumn, when inter-row pasture is of poor quality and in low quantity, suggest shrub material may increase to half of the dry matter (DM) intake of sheep in these circumstances.

FIGURE 3. Effect of shrub density on inter-row pasture biomass



Hence the understorey of complementary plants is critical.

There are three key points to remember:

1. Growing the shrubs often allows better pasture production by:
   - Reducing saline ground water below the root depth of an establishing annual pasture.
   - Reducing wind erosion allowing better pasture establishment and growth.
   - Potentially introducing positive interactions between complementary plant species.
   - Introducing beneficial shading.
2. The shrub component can be a major contributor to providing a nutritionally-balanced diet for productive livestock. For example, the utilisation of the fibre in crop stubbles requires animals to have a source of nitrogen (crude protein). Shrubs can be a quality source of dietary protein, minerals and/or vitamins not necessarily provided by other pasture plants.
3. Animals can only eat a certain amount of any particular food. This is due to either (i) a nutrient deficiency limiting their capacity to make use of any more of the feedstuff and/or (ii) high levels of a plant compound (toxin) that limits their capacity to eat or use any more material. But if another feed is provided, with a different balance of nutrients and plant compounds, the limitations of a single feed may be averted.

It is the total plant mix on offer that sets the ultimate limit to intake and productivity and, in this way, including forage shrubs adds diversity to the diet and the potential to boost intake and livestock performance.

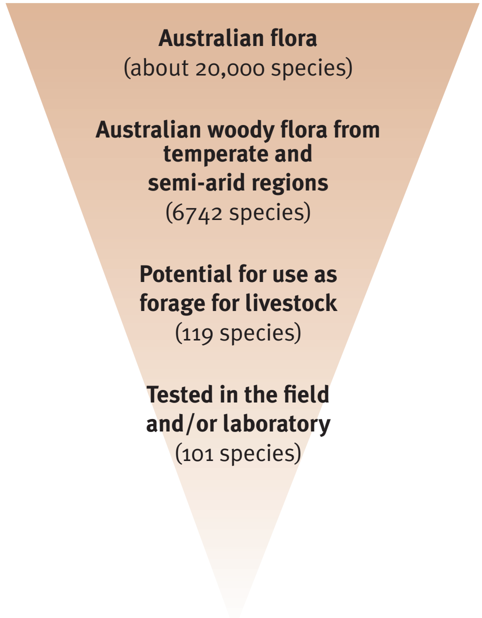
4. Selecting shrub species for profitable and sustainable farming systems

Selecting species with attributes suited to a system offering multiple benefits, and consisting of several species each making up a part of the total offering, creates new opportunities in plant selection. A single species doesn't need to meet all animal requirements, in fact it could be quite weak in some attributes and strong in others, as long as another species fills the missing attribute.

We developed a process for researching potential shrub species based on three main criteria:

1) Having a perennial life habit and woody growth form, so as to include growth forms such as trees and creepers.
2) Being native to the traditional livestock–cropping zone (temperate) or the southern pastoral zone (semi-arid) — a few exotic species were included for comparison.
3) Evidence of being palatable.

FIGURE 4. Shrub species selection process



While this resulted in identifying more than 100 species we know there are other species that may also be eaten that escaped this process. A total of 87 species were successfully grown in the field with research on another 14 species carried out on plants from native locations (see Figure 4).

Data on plant attributes have been gathered primarily from three main sites — Condobolin (NSW), Merredin (WA) and Monarto (SA) — which each have been planted with multiple provenances (genotypes) of more than 50 species. Subsequently, with the support of numerous local groups/organisations another 19 sites across southern Australia have been established, testing a smaller range of species. Further work on detailed grazing studies has also been undertaken at Badgingarra (WA) and Monarto (SA).

As shrub species have the potential to provide a range of benefits, our measurements reflect this.
We have routinely collected data on the following plant attributes:

- Edible biomass.
- Plant growth over time.
- Growth form and height.
- Re-growth after grazing.
- Animal preferences (palatability).
- Nutritive value (protein, fibre, minerals).
- Effects on rumen fermentation (gas production to indicate digestibility).
- Bioactivity — pattern of rumen fermentation end products including methane, ammonia, volatile fatty acid composition.
- Bioactivity — anthelmintic properties.

The following sections outline these traits in more detail and a full list of species information is contained in Section 17.

5. Grazing management with shrubs in a mixed forage system

It is unrealistic to expect animals to perform well at all times with just one or two shrub or pasture species. Providing diversity in the total range of feed on offer is the key.

Grazing herbivores, such as sheep, cattle and goats, are designed to cope with this situation. As livestock managers, we can help by providing the right experiences with which they will make decisions on what to eat and how much to eat. Biological complexity does not necessarily mean difficult management. We do not have to intensively manage all the biological interactions, but we can provide the building blocks.

"Let us permit nature to have her way, she understands her business better than we do"

16th Century French author and 'father of modern skepticism', Michel de Montaigne.

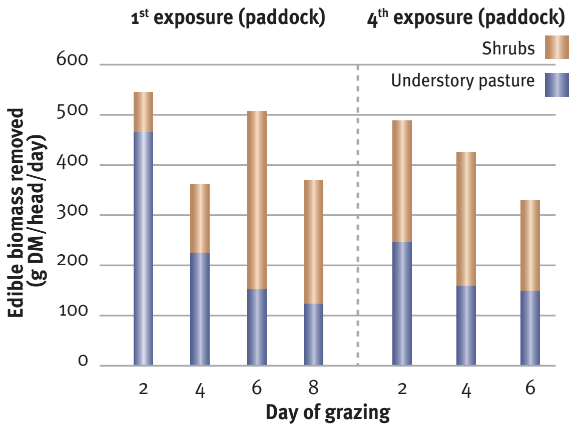
Diet diversity is best achieved through:

- ***High stock density:*** High grazing pressure encourages animals to broaden their selection of plants in the diet. With time this can lead to animals seeking to select a wide range of plant species as a normal and everyday occurrence.
- ***Animals in optimal condition and not stressed:*** This increases the chances of animals successfully exploring new food sources in a diverse mixture of plants.
- ***Experienced animals:*** Allow animals to develop repeated experiences of diverse forages, especially when grazing or browsing shrubs is new to them.

The best way to provide experience is to move animals into new plots or paddocks that contain familiar, nutritious plants before overgrazing their current paddock (see Figure 5). Set-stocking shrub-based paddocks can lead to the pasture being over-grazed before the shrubs are selected. Moderate–high grazing pressure and moving animals into new plots or paddocks allows them to adapt their grazing behaviour and incorporate shrub foliage into the diet before the understorey pasture runs out. This practice may be best managed by having shrubs in multiple paddocks, allowing producers to deliver many repeated 'lessons' to animals. Higher stock densities allow learned experiences to be observed by many animals at once, thus hastening the learning process. This works the same way that exposing a concentrated number of animals to an electric fence instils a fear of electric fences rapidly throughout the group.

The most powerful learning experience occurs when young animals are still with their mothers. The simple exposure of a young animal to a new food at this stage will improve the chances of that animal accepting the new food later in life. Amazingly, this 'learning' or 'programming' can even start in utero (before birth). Lambs born to ewes grazing saltbush during pregnancy and early lactation can perform better when grazing saltbush as weaners compared with flock mates whose mothers had not grazed saltbush.

FIGURE 5. Change in grazing preferences between shrubs and inter-row pasture due to repeated exposure. Hay was provided *ad libitum*.



6. Plant data from the *Enrich* project — shrub edible biomass

Edible biomass production

The shrubs used in grazing systems need to provide sufficient edible biomass to meet animal production and health targets. It is important to avoid focussing on the biomass production of one plant, instead, focus on a collection of plants that determine the number of grazing days available.

Capacity to recover from grazing

Given forage shrubs will often be grazed 'out-of-season' when there are few other feed options available on farm, there will be circumstances when the shrubs are heavily grazed. Plants resilient to the grazing process by surviving and producing new leaf material in preparation for the next grazing event are ideal. Plants that recover well from grazing even under difficult (for example, dry) seasonal conditions are of particular interest.

Top performers for edible biomass — biomass per plant, expressed as a percentage of old man saltbush.

Data was averaged from evaluation sites at Merredin (WA), Monarto (SA), and Condobolin (NSW). Re-growth score is the average biomass 12 months after grazing at Monarto (SA), and is expressed as a percentage of the pre-grazing biomass (see Table 1).

A total of 25 shrub species produced edible biomass of at least one-third of old man saltbush (on a per plant basis). Remember, plant growth will depend on your local conditions, so it can be beneficial to try a few species on a small scale first, to see how they perform.

TABLE 1. Top performers for edible biomass*

Scientific name	Common name	Biomass score at 18 months	Re-growth score
Acacia saligna	Golden wreath wattle	110	97
Atriplex amnicola	River saltbush	108	101
Atriplex nummularia	Old man saltbush	100	88[NB]
Atriplex rhagodioides	Silver saltbush	76	101
Rhagodia preissii	Mallee saltbush	71	95
Maireana tomentosa	Felty bluebush	69	96
Rhagodia parabolica	Mealy saltbush	64	98
Acacia nerifolia	Oleander wattle	63	87
Atriplex leptocarpa	Slender-fruit saltbush	56	
Atriplex vesicaria	Bladder saltbush	53	91
Atriplex semibaccata	Creeping saltbush	53	88
Atriplex paludosa	Marsh saltbush	50	94
Maireana georgii	Satiny bluebush	43	101
Enchylaena tomentosa	Barrier saltbush, ruby saltbush	42	97

** Biomass per plant, expressed as % of old man saltbush.*

NB: Old man saltbush re-growth was affected by heavy competition due to being planted at a high density

7. Plant data from the *Enrich* project — digestibility and rumen fermentation

The feeding value of plants to grazing animals is determined by voluntary feed intake and nutritive value. Nutritive value is a function of digestibility, protein, minerals, vitamins and secondary compounds, and the efficiency with which they are utilised. Some common indicators of nutritive value are neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose (often considered as 'digestible fibre', which is the difference between NDF and ADF), crude protein, and mineral content. The relationships between fibre content and digestibility for conventional pastures are not the same as for Australian shrub species, so it is better to use *in vitro* gas production to gauge the digestibility of a particular species.

Shrub species were tested using a laboratory technique that mimics rumen fermentation. Feed was incubated with a mixed population of rumen microbes (rumen fluid) in a sealed vessel, and the end products of microbial fermentation (for example, total gas production and volatile fatty acids, see Table 2) and consequences (for example, acidity, or pH, of rumen fluid) were measured. Volatile fatty acids are the main sources of energy available to ruminant livestock from the fermentation of plant material.

Of more than 100 samples tested, 52 had a rumen 'fermentability' (digestibility) similar to, or higher than, the control of oaten chaff.

TABLE 2. Top performers for 'fermentability' (digestibility) and production of volatile fatty acids by rumen microbes

Scientific name	Common name	Gas production ('fermentability') (kPa)	Volatile fatty acid production (mM)
	Oaten chaff (control)	**84**	**92**
Cullen australasicum	Tall verbine	103	113
Medicago citrina (not native to Australia)	Alfalfa arborea	100	105
Medicago strasseri (not native to Australia)	Tree medic	99	102
Medicago arborea (not native to Australia)	Moon trefoil	94	86
Convolvulus remotus	Australian bindweed	94	90
Brachyscome ciliaris	Variable daisy	92	80
Swainsona greyana	Hairy darling pea	91	114
Glycine clandestina	Twining glycine, love creeper	90	94
Glycine canescens	Silky glycine	88	96
Glycine tabacina	Glycine pea	87	83
Eremophila bignoniifolia	Bignonia emu bush, creek wilga, dogwood	86	80
Atriplex nummularia	Old man saltbush	84	104
Chameacystisus prolifer (not native to Australia)	Tagasaste	81	106
Atriplex amnicola	River saltbush	80	84
Rhagodia parabolica	Mealy saltbush	78	103
Rhagodia preissii	Mallee saltbush	78	103
Rhagodia candolleana	Sea berry saltbush	77	84

8. Plant data from the *Enrich* project — crude protein

Low plant protein levels often limit animal production when livestock graze dry pastures or stubbles. Fortunately, forages with a high nitrogen (or crude protein) content can improve the efficiency with which ruminant livestock can utilise such fibrous plant material.

The average crude protein content across all species tested was 17 per cent, ranging from 8 to 26 per cent. Virtually all shrubs tested met the minimum protein requirements for adult sheep to maintain liveweight. A total of 43 shrub species had a crude protein content of >15 per cent, which is about the amount required for growing weaner animals.

Note: *Crude protein measures both 'true protein' and 'non-protein nitrogen' (such as nitrate). Not all of the non-protein nitrogen is available to the rumen microbes as true protein and care is needed in managing animals on high-nitrate plants if they represent a large portion of the plants on offer.*

TABLE 3. The top 10 species for crude protein content

Scientific name	Common name	Crude protein (%)
Maireana georgii	Satiny saltbush	26
Malva preissiana	Australian or native hollyhock	25
Maireana tomentosa	Felty bluebush	25
Maireana convexa	Mulga bluebush	24
Chenopodium auricomum	Golden goosefoot	24
Maireana brevifolia	Small leaf bluebush, yanga bush	23
Maireana sedifolia	Pearl bluebush	23
Rhagodia drummondi	Lake fringe rhagodia	23
Maireana pyrimadata	Sago bush, black bluebush	23
Einadia nutans	Nodding saltbush, climbing saltbush	22
Atriplex rhagodioides	Silver saltbush	22

9. Plant data from the *Enrich* project — minerals

Macro-minerals and trace elements are essential nutrients for livestock. Producers often provide a mineral block for their livestock to correct deficiencies. The risk of mineral or trace element deficiencies depends on the location, soil mineral content and fertiliser history. Minerals are often referred to as micro-nutrients or trace elements — but remember they have this name because only small amounts are needed, not because they are unimportant.

As a generalisation, we have found many of the Australian shrub species tested were high in mineral content (see Table 4) and some were high in vitamin E as well. Consider them as 'standing supplements'. Indeed, some are so high in some minerals that toxicity could be a problem, but only if the plant was the sole, or dominant, feed source. Also, we do not yet know the bio-availability of the minerals in these shrubs — how much of the minerals in the edible biomass are actually available to the animal grazing them. In a recent PhD project, sheep fed 100 per cent saltbush had a net loss of calcium, magnesium and phosphorus even though the saltbush leaves contained these minerals well in excess of requirements. So to reduce the risks of toxicities or deficiencies, using a mixture of plants is a sensible option.

TABLE 4. Some top performers for mineral content

Scientific name	Common name	Ca (g/kg)	Mg (g/kg)	P (g/kg)	S (g/kg)	Cu (mg/kg)	Zn (mg/kg)
		Dietary requirement					
		1–3	1–1.5	1.3–2.5	2	2–7	20–30
Acacia ligulata	Umbrella bush, sandhill wattle	30.1	6.7	0.6	21.2	1.6	9
Atriplex isatidea	Coastal saltbush	16.9	11.9	0.7	2.7	15.4	42
Atriplex cinerea	Grey saltbush	16.9	9.8	1.1	3.8	11.1	42
Rhagodia preissii	Mallee saltbush	8.4	10.7	1.6	3.7	9.4	35
Rhagodia spinescens	Thorny saltbush	5.7	10.2	1.5	4.4	4.9	20
Atriplex amnicola	River saltbush	7.7	9.6	1.7	5.6	7.2	26
Chenopodium nitrariaceum	Nitre goosefoot	7.3	9.3	1.6	3.8	5.1	23
Atriplex nummularia	Oldman saltbush	12.9	8.6	1.7	6.5	12.3	55
Atriplex rhagodioides	Silver saltbush	6.2	8.4	1.4	5.5	5.5	20
Malva preissiana	Australian or native hollyhock	20.5	7.3	2.5	9.1	6.2	25
Atriplex paludosa	Marsh saltbush	8.1	6.9	1.2	4.2	4.2	22
Atriplex leptocarpa	Slender-fruit saltbush	16.5	6.6	1.5	6.7	6.7	21
Chenopodium auricomum	Golden goosefoot	6.8	8.7	1.2	5.4	4.4	22
Swainsona greyana	Hairy darling pea	12.9	5.4	2.1	3.0	9	28
Rhagodia drummondi	Lake fringe rhagodia	9.4	15.5	2.1	4.1	5.8	33

10. Plant data from the *Enrich* project — rumen bioactivity

Secondary plant compounds (i.e. natural plant chemicals that can be considered as either 'extra-nutritional' or 'anti-nutritional' depending on the chemical and its concentration in the plant or diet) can modify the fermentation of plant material in the rumen of livestock. The data in Table 5 lists shrub species that reduced methane production, which is a desirable trait because methane is a loss of energy from the animal and is a greenhouse gas. Also shown is the ammonia production per unit of crude protein in the plant material, where a low value is often considered a valuable trait because it indicates a lower breakdown of dietary protein.

Fifteen plants (12 per cent of those tested) reduced methane production without reducing total gas production from fermentation, which is an exciting prospect. The fermentation of all shrubs tested led to lower ammonia levels compared with the oaten chaff control; this too is a very encouraging result.

TABLE 5. **Top performers for *reduced* methane and low ammonia production**

Scientific name	Common name	Methane (ml/g dry matter)	Ammonia (mg/g crude protein)
	Oaten chaff (control)	**45**	**384**
Acacia loderi	Broken Hill gidgee, nelia	8	68
Lotus australis	Austral trefoil	13	65
Acacia pycnantha	Golden wattle	13	87
Acacia saligna	Golden wreath wattle	14	132
Eremophila glabra	Tar bush	16	101
Brachychiton gregorii	Desert kurrajongs	16	58
Atalaya hemiglauca	Whitewood, cattle bush	17	54
Acacia neriifolia	Oleander wattle	17	49
Acacia iteaphylla	Flinders Range wattle	17	66
Maireana convexa	Mulga bluebush	21	68
Kennedia eximia	Red coral vine	25	20
Maireana brevifolia	Small leaf bluebush, yanga bush	25	198
Rhagodia candolleana	Sea berry saltbush	26	132
Kennedia prorepens	Purple flowered pea vine	26	96
Acacia ligulata	Umbrella bush, sandhill wattle	28	69
Chenopodium nitrariaceum	Nitre goosefoot	28	96
Rhagodia preissii	Mallee saltbush	32	154
Chameacystisus prolifer (not native to Australia)	Tagasaste	32	172
Enchylaena tomentosa	Barrier saltbush, ruby saltbush	33	189

11. Plant data from the *Enrich* project — anthelmintic properties (reducing gut parasites)

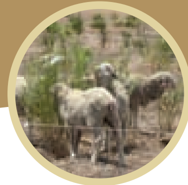
A component of the *Enrich* project has been to identify shrub species that may provide a degree of control of parasitic worms in grazing livestock. We used a laboratory method that measured the development of parasite larvae when exposed to plant material from the shrubs being evaluated. Significant anthelmintic activity has been found in many of the shrub species. This work is at an early stage of development and while there are exciting possibilities emerging, the steps from this stage of screening to practical application on farm will take several years. Table 6 lists a selection of the shrub species that showed significant anthelmintic activity in laboratory assays. Extracts from these plants inhibited larval development in these assays by more than 50 per cent.

A total of 23 species, or 40 per cent of the species tested, reduced gastrointestinal parasite development to half or less than the control.

There are two other benefits of a shrub-based system for parasite control. The first is that when animals browse shrubs they are not ingesting parasite larvae as they feed at a height above that occupied by the parasite larvae on ground-level pasture. The second benefit is that a rotational grazing system and moving animals into 'clean' paddocks (as recommended with a mixed forage system with shrubs) also avoids the consumption of parasite larvae and helps break the parasite life cycle.

TABLE 6. Shrub species showing anthelmintic properties

Scientific name	Common name	Parasite development score (% of control)
Viminaria juncea	Swishbush, golden spray	<1
Eremophila maculata	Native fuschia	2
Chenopodium nitrariaceum	Nitre goosefoot	3
Acacia pycnantha	Golden wattle	6
Acacia loderi	Broken Hill gidgee, nelia	9
Acacia saligna	Golden wreath wattle	10
Eremophila longifolia	Emu bush, Berrigan	10
Medicago sativa (not native to Australia)	Lucerne	10
Kennedia eximia	Red coral vine	12
Kennedia prorepens	Purple flowered pea vine	29
Rhagodia candolleana	Sea berry saltbush	42
Enchylaena tomentosa	Barrier saltbush, ruby saltbush	49



12. Plant data from the *Enrich* project — palatability

Any plants considered for grazing systems must be acceptable to the animals. We routinely assess whether animals select the plants on offer, and refer to this as the 'palatability' of the plant. However, exercise caution when considering this attribute as there can be large variability within the plant species, depending on the provenance of the species (i.e. where it was originally sourced from), where it is grown, and its stage of growth (for example, vegetative, flowering or fruiting). The palatability of a plant, or the preference animals show for or against it when a choice is available, is determined by the plant's odour and flavour, and physiological and metabolic effects on the animal after it has been ingested. But it's important to also realise that the palatability of a particular plant depends not just on the characteristics of the plant, but on the animals too: **it depends on what other feeds are offered with it, the animal's experience with the plant, and the grazing density or pressure** (see Section 5).

About 40 per cent of the shrubs tested can be considered as having high palatability and animals readily eat them when they are first offered (see Table 7). Another 40 per cent have moderate palatability, which means animals eat them, but often not as their first choice, at least when they have limited experience with them. The selection of these plants often increases over time as animals develop experience. About 20 per cent of the shrubs tested have low palatability and are strongly avoided, although some of these are eventually eaten when choice is limited.

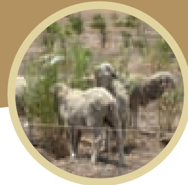


TABLE 7. Some of the plants with a high palatability rating, averaged across grazing studies at Merredin (WA), Monarto (SA) and Condobolin (NSW).

Scientific name	Common name	Scientific name	Common name
Acacia ligulata	Umbrella bush, sandhill wattle	*Eremophila glabra*	Tar bush
Acacia neriifolia	Oleander wattle	*Eremophila longifolia*	Emu bush, Berrigan
Acacia pycnantha	Golden wattle	*Kennedia eximia*	Red coral vine
Acacia saligna	Golden wreath wattle	*Kennedia macrophylla*	Augusta Kennedia
Allocasuarina verticillata	Drooping sheoak	*Kennedia nigricans*	Black Kennedia
Atriplex amnicola	River saltbush	*Kennedia prostrata*	Scarlet runner, running postman
Atriplex cinerea	Grey saltush	*Kennedia rubicunda*	Dusky coral pea
Atriplex isatidea	Coastal saltbush	*Lotus australis*	Austral trefoil
Atriplex vesicaria	Bladder saltbush	*Maireana convexa*	Mulga bluebush
Chameacytisus prolifer	Tagasaste	*Medicago arborea*	Moon trefoil
Chenopodium auricomum	Golden goosefoot	*Medicago sativa*	Lucerne
Cullen australasicum	Tall verbine	*Medicago strasseri*	Tree medic
Eremophila bignoniiflora	Bignonia emu bush, creek wilga, dogwood	*Viminaria juncea*	Swishbush, golden spray

13. Shrubs for shelter

Providing livestock with shade and shelter has a direct impact on animal production by decreasing lamb and off-shears mortality and by reducing the animal's energy requirements during extreme weather conditions. Reducing wind speed also reduces the risk of wind erosion.

The area of shelter is directly proportional to the height of the vegetation providing the shelter. Maximum shelter is provided on the leeward side of the shelter and extends for about 10 times its height. The effectiveness of using plants as shelter depends on the orientation and length of planting and the vegetation's permeability. Plant shrubs that are to be used for shelter at right angles to the prevailing wind(s) and ensure rows are of sufficient length as winds tend to eddy around the edges of the row. Permeability in the vegetation allows some wind through at a slower speed and results in protection across a wider area. However, dense vegetation can give adequate shelter in small paddocks, such as old man saltbush planted at a high density.

Rows of a mixture of tall and shorter species are the best way to achieve even permeability and adequate height (see Table 8). Using just tall species can lead to increased wind speed under trees where livestock have grazed all the lower branches. When planted in multiple rows, a vertical face of vegetation is more effective at slowing the wind than a sloping face of short, medium and then tall species. Spirals or boomerang planting arrangements have also been used effectively to provide protection from the wind (at no extra establishment cost).

TABLE 8. Suggestions of species suitable for shelter. Species also providing good shade indicated by an asterisk (*)

Shorter	Medium	Tall
Atriplex nummularia (old man saltbush)	*Acacia ligulata* (sandhill wattle)	*Acacia loderi* (nelia)*
Atriplex rhagodioides (silver saltbush)	*Acacia oswaldii* (Oswald's wattle)*	*Acacia neriifolia* (oleander wattle)
Rhagodia parabolica (mealy saltbush)	*Acacia saligna* (golden wreath wattle)*	*Acacia pendula* (myall)*
Rhagodia preissii (mallee saltbush)	*Allocasuarina verticillata* (drooping sheoak)	*Geijera parviflora* (wilga)*

14. Considerations for designing a shrub-based grazing system

In addition to achieving better feed utilisation and animal performance by providing diversity in the diet of livestock, using multiple shrub species is the way to realise as many of the potential multiple benefits as possible. Most species do not have all of the attributes that may be required — for example, they may be high in crude protein but do not show any potential for controlling intestinal worms or providing shade. However, by growing a mix of species, each of which provides an attribute, a range of multiple benefits is possible (see Table 9).

TABLE 9. An example of shrub selection considerations to achieve multiple benefits

	High biomass	High crude protein	Parasite mitigation	Shade
Species A	✔	✔		
Species A + species B	✔	✔	✔	
Species A + species B + species C	✔	✔	✔	✔

There is no single right way to arrange and design a shrub planting. However, there are a few important points to consider:

- The inter-row pasture will be the major component of the biomass produced and so consider being able to manage this.
- Access with machinery between shrub rows can be impossible when planted densely. That minimises the capacity to re-sow different pasture or for spraying and other operations.
- Mustering stock in dense stands can also be difficult. Some producers plant shrubs in widely-spaced rows (alleys) and grow crops or pasture between the shrubs. However, achieving high grazing pressure can be difficult in these situations if paddock subdivisions are too large for the mob size.

The shrub species mentioned in this booklet do not all have the same growth habit and potential size, and so would have different optimum planting densities. For example, old man saltbush would need fewer plants to achieve optimum density than the smaller creeper, scarlet runner (*Kennedia prostrata*). However, as yet we have not carried out research to address these issues.

While growing multiple species is beneficial, they do not necessarily need to be grown close together (for example, in the same row). What is more important is that animals have access to a diverse range of plants. Having species grown separately may also be easier to plant and manage agronomically.

15. Let the animals decide

The data presented in this booklet show clearly that many shrubs possess positive characteristics. Also, no single shrub species can provide all of the attributes we'd like. This reinforces the approach to include a mixture of plant species for livestock grazing systems. By offering a range of plants, animals can choose to 'mix and match' their diet.

Animals, especially herbivores, select their diet by associating the metabolic consequences of eating a particular feedstuff with its sensory charactertistics of sight, smell and taste. Herbivores come hardwired to adapt to the many biochemical signals of eating different feedstuffs. Our role in managing grazing animals is to provide them with a range of food choices and allow them to learn about the relative merits of the different plants on offer.

Many studies have shown that grazing animals consistently select a diet more nutritious than the average quality of what's on offer. Maybe half a dozen plants make up the bulk of a meal, but during the course of a day animals can nibble on 50 to 100 different plants, each with their own nutrient and secondary compound profiles. In the *Enrich* project, we have repeatably seen animals select a wide range of shrub species. Importantly, the animals often selected this diverse mix even when they could have consumed a more simple diet of inter-row pasture.

Generally animals avoid foods low in nutrients and likewise eat limited amounts of foods too high in nutrients. Of importance here is the animal's capacity to learn. For example, take the scenario of an animal being offered several foods, one of which is a new food it has not encountered before — the animal consumes a meal that consists of all foods in different proportions. If the consumption of the meal overcomes a nutrient deficiency, the animal will associate recovery from the deficiency with the new food. Conversely, if the meal is followed by toxicosis, the animal will acquire an aversion to the new food.

The reason grazing animals select what they eat is more than a matter of taste. With time, animals 'like' foods that provide nutrients and compounds needed for health and 'dislike' foods that compromise nutrition or health. In this way, an animal's liking for a food (or plant) can change based on the feedback signals that arise in their body.

You can find more information on the interactions between plants, animals and the landscape at a website hosted by Utah State University that captures much of the work of Professor Fred Provenza and his colleagues over many years: **www.behave.net/**. There is a comprehensive bibliography under 'educational products' and plenty of practical suggestions as well.

In summary, herbivores have the capacity to learn about the feeds on offer to them and select a diet to optimise their nutritional state and/or minimise their metabolic cost. They can only do this when they have a diverse set of familiar options on offer.

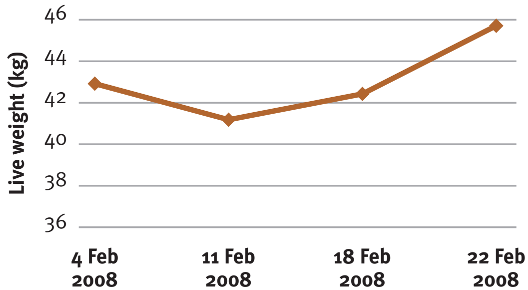
16. Animal performance

The successful use of forage shrubs is built upon the (i) timeliness of providing extra 'green' feed when other conventional forage sources are in poor supply and typically of poor quality and (ii) the capacity of animals to consume adequate amounts of the shrub and inter-row forage to reach production targets.

We have shown that with shrub-based forage systems, sheep can gain weight without supplementary feeding during autumn. This is a big change from the poor animal performance during the autumn feed gap of Mediterranean and temperate regions and/or the high reliance on supplementary (hand) feeding.

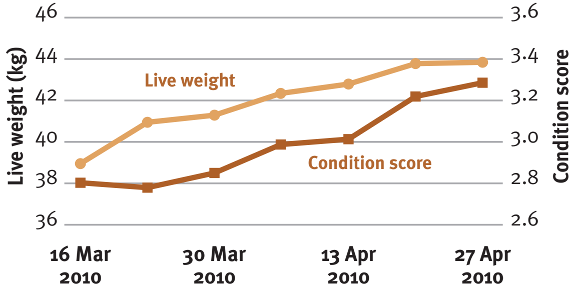
At a research site at Badgingarra north of Perth WA, sheep gained weight during February 2008, which was only 18 months since the shrub seedlings were planted (see Figure 6). The bulk of the feed on offer at this time, given the shrubs were still growing, was the inter-row pasture, but the shrubs provided the necessary 'top-up' to the poor quality annual pasture, preventing animals from losing weight. The young shrubs effectively replaced the need for hand-feeding. Weight gain during February was achieved across three widely different stocking rates. The animals used in this experiment were naïve to forage shrubs (the principles outlined in Section 15 were not followed) and took a few weeks to recover from an initial dip in liveweight when first moved onto the shrub-based pasture.

FIGURE 6. Weight gain in sheep grazing forage shrubs



At the same site two years later, with fully-established shrubs and inter-row pasture at 2.5–3.0 t DM/ha, sheep gained more than 100 g/day and 0.5 of a condition score across six weeks during autumn (at 10 DSE/ha) — see Figure 7.

FIGURE 7. Weight gain and condition score of sheep grazing forage shrubs during autumn



In addition to showing the direct benefits of grazing shrub-based systems 'out-of-season', the grazing studies at the Badgingarra site has also confirmed three important principles:

1. Animals at high grazing density will consume a broad range of shrub species on a daily basis. At the research site, sheep grazing at a high stocking rate and moved onto a new plot every day consumed >60 per cent of the available foliage from five shrub species each day. At a low stocking rate, the daily intake did not include such a wide range of shrubs.
2. The intake of shrub species that have less-than-average palatability increases if animals have a positive experience. We found sheep with experience of *Rhagodia preissii* (mallee saltbush) ate most of the leaves from 35–40 per cent of the individual plants, but inexperienced sheep consumed most of the leaves from only about 20 per cent of plants (see below).
3. The best combination of liveweight gain and high utilisation of shrubs was obtained when animals had access to multiple shrub species simultaneously, rather than either having just one shrub species available or rotating between shrub species.

17. Further information

All species tested in the *Enrich* project for mineral and nutritional value and/or measured for productivity and selection by sheep are listed below. The number of ticks indicates how well each species met the target for each trait (see Legend page 43) .

TABLE 9. *Enrich* species tested for biomass production, nutritional value and grazing preference

Scientific name	Common name	Edible biomass (pre-first grazing) Percentage of old man saltbush on a per-plant basis			Palatability (average of multiple grazings)	Crude protein	Digestibility	Bioactivity (methane production and parasite development)	Calcium[1]	Copper[1]	Magnesium[1]	Phosphorus[1]	Sulphur[1]	Zinc[1]
		Condobolin (NSW)*	Merredin (WA)+	Monarto (SA)#										
Abutilon otocarpum	Desert lantern			✔	✔	✔✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Acacia aneura	Mulga			✔	✔✔									
Acacia brachybotrya	Grey mulga			✔	✔									
Acacia estrophiolata	Iron wood			✔	✔									
Acacia iteaphylla	Flinders Ranges wattle			✔	✔	✔✔	✔	✔✔✔	✔✔	✔✔	✔✔	✔	✔	✔
Acacia kempeana	Whitchetty bush			✔	✔✔		✔	✔✔✔						
Acacia ligulata	Sandhill wattle	✔✔	✔	✔	✔✔	✔	✔	✔✔✔	✔✔✔	✔	✔✔✔	✔	✔✔✔	✔
Acacia loderi	Nelia			✔	✔✔	✔	✔	✔✔✔	✔✔	✔✔	✔✔	✔	✔	✔
Acacia myrtifolia	Myrtle wattle			✔	✔	✔	✔	✔✔	✔✔	✔✔	✔✔✔	✔	✔	✔
Acacia neriifolia	Oleander wattle	✔	✔✔✔	✔	✔✔✔	✔✔	✔	✔✔✔	✔✔	✔✔	✔✔	✔	✔	✔
Acacia pendula	Myall			✔	✔	✔✔			✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔

Acacia pycnantha	Golden wattle	✔		✔	✔✔✔	✔	✔	✔✔✔	✔✔✔	✔✔	✔✔	✔	✔	✔
Acacia saligna	Golden wreath wattle		✔✔✔	✔	✔✔✔	✔	✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔
Acacia victoriae	Elegant wattle			✔	✔✔									
Alectryon oleifolius	Bullock bush			✔		✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔	✔✔✔
Allocasuarina muelleriana	Salty sheoak			✔	✔✔									
Allocasuarina verticillata	Drooping sheoak	✔	✔	✔	✔✔✔	✔			✔✔✔	✔✔	✔✔	✔	✔✔	✔✔
Atalaya hemiglauca	Whitewood			✔	✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔
Atriplex amnicola	River saltbush	✔✔✔	✔✔✔	✔	✔✔	✔✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Atriplex cinerea	Grey saltbush	✔	✔	✔	✔✔	✔✔	✔✔	✔	✔✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔✔✔
Atriplex isatidea	Coastal saltbush	✔	✔	✔	✔✔	✔	✔	✔✔	✔✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔✔✔
Atriplex leptocarpa	Slender fruit saltbush			✔	✔	✔✔			✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Atriplex nummularia	Old man saltbush	✔✔	✔✔	✔✔	✔	✔✔	✔✔	✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔✔
Atriplex paludosa	Swamp saltbush	✔	✔	✔	✔	✔✔	✔	✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔✔
Atriplex rhagodioides	Silver saltbush	✔✔	✔✔	✔	✔	✔✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Atriplex semibaccata	Creeping saltbush	✔	✔	✔	✔✔	✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔
Atriplex vesicaria	Bladder saltbush	✔	✔	✔	✔	✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔
Brachychiton gregorii	Desert kurrajong			✔	✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔✔✔
Brachychiton populneus	Kurrajong			✔	✔✔	✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔✔
Brachyscome ciliaris	Variable daisy			✔	✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Capparis mitchellii	Wild orange			✔		✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔✔✔
Chamaecytisus prolifer	Tagasaste	✔	✔	✔	✔✔✔	✔✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔	✔✔✔
Chenopodium auricomum	Golden goosefoot	✔	✔	✔	✔✔✔	✔✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Chenopodium gaudichaudianum	Scrambling saltbush	✔	✔	✔	✔	✔✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Chenopodium nitrariaceum	Nitre goosefoot	✔	✔	✔	✔	✔✔✔	✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔

Continued next page

TABLE 9. *Enrich* species tested for biomass production, nutritional value and grazing preference (continued)

Scientific name	Common name	Edible biomass (pre-first grazing) — Percentage of old man saltbush on a per-plant basis			Palatability (average of multiple grazings)	Crude protein	Digestibility	Bioactivity (methane production and parasite development)	Calcium[1]	Copper[1]	Magnesium[1]	Phosphorus[1]	Sulphur[1]	Zinc[1]
		Condobolin (NSW)*	Merredin (WA)+	Monarto (SA)#										
Convolvulus remotus	Grassy bindweed	✔		✔	✔✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔	✔
Cratystylis conocephala	Bluebush daisy			✔			✔	✔✔						
Cullen australasicum	Native verbine	✔	✔	✔	✔✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔✔
Cullen cinereum	Annual verbine			✔	✔✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔
Cullen discolor	Grey scurf pea					✔✔✔	✔	✔✔						
Cullen pallidum	Hairy verbine			✔	✔✔	✔✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔✔✔
Cullen parvum	Small scurf pea					✔✔	✔✔	✔✔						
Cullen patens	Spreading scurf pea					✔✔✔	✔✔	✔						
Cullen tenax	Tough scurf pea, emu foot					✔✔✔	✔	✔						
Dorycnium hirsutum	Hairy canary clover			✔	✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔
Einadia nutans	Climbing saltbush	✔		✔	✔	✔✔✔			✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔✔
Enchylaena tomentosa	Ruby saltbush	✔	✔	✔	✔✔	✔✔	✔	✔✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Eremophila alternifolia	Narrow leaf fuchsia bush			✔	✔✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Eremophila bignoniiflora	Bignonia emu bush	✔	✔	✔	✔✔✔	✔	✔✔	✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔	✔✔
Eremophila glabra	Tar bush	✔	✔	✔	✔✔✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔✔
Eremophila longifolia	Emu bush	✔	✔	✔	✔✔✔	✔	✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔	✔	✔
Eremophila maculata	Spotted fuchsia bush	✔		✔	✔✔	✔✔	✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔

Geijera parviflora	Wilga						✔✔	✔						
Glycine canescens	Silky glycine	✔		✔	✔✔✔	✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔✔
Glycine clandestina	Twining glycine			✔	✔✔	✔✔	✔✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔
Glycine tabacina	Glycine pea			✔	✔✔	✔✔	✔✔	✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔	✔✔
Jasminum didymum	Native jasmine						✔	✔✔						
Kennedia eximia	Red coral vine		✔	✔	✔✔✔	✔	✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔	✔	✔
Kennedia macrophylla	Augusta Kennedia		✔	✔	✔✔✔	✔	✔	✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔
Kennedia nigricans	Black Kennedia	✔	✔	✔	✔✔✔	✔✔	✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔✔
Kennedia prorepens	Purple flowered pea vine			✔	✔✔✔	✔	✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔
Kennedia prostrata	Running postman	✔	✔	✔	✔✔✔	✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔✔
Kennedia rubicunda	Dusky coral pea		✔	✔	✔✔✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔
Lolium /Avena spp.	Annual grasses				✔✔✔	✔			✔✔✔	✔✔	✔✔✔	✔✔✔	✔✔✔	✔
Lotus australis	Austral trefoil	✔	✔	✔	✔✔✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔✔
Maireana astrotricha	Low bluebush			✔	✔	✔✔✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔
Maireana brevifolia	Small leaf bluebush	✔	✔	✔	✔	✔✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔
Maireana convexa	Mulga bluebush	✔	✔	✔	✔	✔✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔
Maireana georgei	Satiny bluebush	✔	✔✔	✔	✔✔	✔✔✔	✔✔	✔✔	✔✔✔	✔✔	✔✔	✔✔	✔✔✔	✔
Maireana planifolia	Flat leaf bluebush					✔✔✔	✔✔	✔✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔
Maireana pyramidata	Black bluebush	✔✔	✔	✔	✔	✔✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔
Maireana sedifolia	Pearl bluebush	✔	✔	✔	✔	✔✔✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔
Maireana tomentosa	Felty bluebush	✔✔✔	✔	✔	✔✔	✔✔✔	✔	✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔
Malva preissiana	Australian hollyhock			✔	✔✔	✔✔✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Medicago arborea	Tree medic	✔	✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Medicago citrina	Alfalfa arborea			✔	✔✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔	✔
Medicago sativa	Lucerne	✔		✔	✔✔✔	✔✔✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Medicago spp.	Annual medics				✔✔✔	✔✔✔			✔✔✔	✔✔✔	✔✔✔	✔✔✔	✔✔✔	✔✔
Medicago strasseri	Moon trefoil	✔		✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔

Continued next page

TABLE 9. *Enrich* species tested for biomass production, nutritional value and grazing preference (continued)

Scientific name	Common name	Edible biomass (pre-first grazing) Percentage of old man saltbush on a per-plant basis: Condobolin (NSW)*	Merredin (WA)+	Monarto (SA)#	Palatability (average of multiple grazings)	Crude protein	Digestibility	Bioactivity (methane production and parasite development)	Calcium[1]	Copper[1]	Magnesium[1]	Phosphorus[1]	Sulphur[1]	Zinc[1]
Myoporum platycarpum	Sugarwood			✔	✔✔	✔			✔✔✔	✔✔	✔✔	✔✔	✔✔✔	✔
Pterocaulon sphacelatum	Fruit salad plant	✔		✔	✔	✔✔	✔✔	✔✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Rhagodia candolleana	Sea berry saltbush	✔	✔	✔	✔	✔✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔
Rhagodia crassifolia	Fleshy saltbush	✔	✔	✔	✔	✔✔	✔✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔
Rhagodia drummondii	Lake fringe rhagodia	✔✔✔	✔	✔	✔	✔✔✔			✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Rhagodia eremaea	Tall saltbush	✔✔	✔	✔	✔	✔✔✔			✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Rhagodia parabolica	Mealy saltbush	✔✔	✔✔	✔✔	✔	✔✔	✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Rhagodia preissii	Mallee saltbush	✔✔	✔✔	✔	✔	✔	✔✔	✔✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Rhagodia spinescens	Thorny saltbush	✔✔	✔	✔	✔	✔✔✔	✔	✔	✔✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Sida corrugata	Corrugated sida						✔	✔✔						
Sida intricata	Twiggy sida						✔✔✔	✔✔						
Swainsona greyana	Hairy darling pea	✔		✔	✔✔✔	✔✔✔	✔✔✔	✔	✔✔✔	✔✔✔	✔✔✔	✔✔	✔✔✔	✔✔
Swainsona stipularis	Orange darling pea			✔		✔✔✔	✔✔	✔						
Templetonia retusa	Cockies tongue			✔	✔	✔	✔✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔	✔
Teucrium racemosum	Grey germander			✔	✔✔		✔✔	✔✔						
Viminaria juncea	Golden spray	✔	✔✔	✔	✔✔	✔	✔	✔✔	✔✔✔	✔✔	✔✔✔	✔	✔✔✔	✔

* 427 mm average annual rainfall, non-seasonally distributed, red gradational and red-brown earths with near neutral pH and low inherent fertility and organic matter.
+ 314 mm average annual rainfall, winter-dominant rainfall, long dry summers, loamy sand (yellow sandplain), pH 5.8–6.8.
# 375mm average annual rainfall, winter-dominant rainfall, dry summers, loam over poorly structured clay, pH 7–9.6.

Legend

	✔	✔✔	✔✔✔
Edible biomass (at 18 months pre-grazing)	Edible biomass lower than old man saltbush	Edible biomass equal than old man saltbush	Edible biomass higher than old man saltbush
Palatability (assessed by defoliation during grazing)	Low	Medium	High
Crude protein (percentage of dry matter)	<15	15–19	≥20
Digestibility (assessed by gas produced by rumen microbes during fermentation of plant material in a laboratory test)	Fermentability lower than oaten chaff	Fermentability equal than oaten chaff	Fermentability higher than oaten chaff
Bioactivity (assessed using plant material in a laboratory tests)	No reduction in methane production compared with oaten chaff and parasite larvae development more than 40%	Less methane production than oaten chaff OR parasite larvae development less than 40%	Less methane production than oaten chaff AND parasite larvae development less than 40%
[1]**Calcium**	Less than the animal's requirement (<1 g/kg)	Meets the animal's requirement (1 –3 g/kg)	More than the animal's requirement (>3 g/kg)
[1]**Copper**	Less than the animal's requirement (<2 mg/kg)	Meets the animal's requirement (2–7 mg/kg)	More than the animal's requirement (>7 mg/kg)
[1]**Magnesium**	Less than the animal's requirement (<1 g/kg)	Meets the animal's requirement (1–1.5g/kg)	More than the animal's requirement (>1.5g/kg)
[1]**Phosphorus**	Less than the animal's requirement (<1.3g/kg)	Meets the animal's requirement (1.3–2.5g/kg)	More than the animal's requirement (>2.5 g/kg)
[1]**Sulphur**	Less than the animal's requirement (<1.5g/kg)	Meets the animal's requirement (1.5–2 g/kg)	More than the animal's requirement (>2 g/kg)
[1]**Zinc**	Less than the animal's requirement (<20 mg/kg)	Meets the animal's requirement (20–30 mg/kg)	More than the animal's requirement (>30 mg/kg)

[1] Mineral requirements depend on the animals' physiological state, breed and species.

The *Enrich* project started during 2004 and scores of people have contributed to it in many ways.

This includes researchers and technical staff in seven organisations across four States of Australia. We also had tremendous support from many regional groups, including farmer groups, catchment management authorities (CMAs), natural resource management (NRM) groups and local shires. Individual producers have also contributed, by providing land for research or feedback on our work. The project started with four funding partners: **The Future Farm Industries CRC**, **Meat and Livestock Australia**, **Australian Wool Innovation** and the **Joint Venture Agroforestry Program**. The **FFI CRC** and **MLA** remain involved and new *Enrich* partner projects have started with the support of the **Department of Agriculture Forestry and Food (DAFF)**. A full list of people who have contributed runs into many pages and, while we cannot list them here, we certainly acknowledge their support. Such support has been vital to our progress with the research and initial on-farm adoption of forage shrub species into grazing systems in the low-to-medium rainfall areas of southern Australia. The continued support of this kind will ensure more productive, profitable and sustainable grazing systems for the future.

The current contacts in the *Enrich* research team include; Dean Revell , Nathan Phillips, Andrew Kotze and Hayley Norman (**CSIRO**), Jason Emms and Steve Hughes (**SARDI**), Phil Vercoe and Zoey Durmic (**UWA**), Peter Jessop (**I&I NSW**) and Tanya Kilminster (**DAFWA**). Mike Bennell (formerly of **DWLBC**) had a major role in the first phase of the project.

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