



An Australian Government Initiative



Integrating Forage Shrubs

***Their potential in mixed-farming enterprises
in low rainfall regions***

by Carolyn de Koning and Peter Milthorpe

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Researcher Contact Details

Dr Carolyn de Koning
SARDI, C/- Turretfield Research Centre
ROSEDALE SA 5350
Phone: 08 8524 9661
Fax: 08 8524 9088
Email: dekoning.caroline@saugov.sa.gov.au

Mr Peter Milthorpe
NSW Agriculture, P.O. Box 337
CONDOBOLIN NSW 2877
Phone: 02 6895 2912
Fax: 02 6895 2688
Email: petermil2@bigpond.com

In submitting this report, the researcher has agreed to RIRDC publishing this material in its edited form.

RIRDC Contact Details

Rural Industries Research and Development Corporation
Level 2, 15 National Circuit
BARTON ACT 2600
PO Box 4776
KINGSTON ACT 2604

Phone: 02 6271 4100
Fax: 02 6271 4199
Email: rirdc@rirdc.gov.au
Web: <http://www.rirdc.gov.au>

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Foreword

This literature review examines the prospects for integrating forage shrubs into low rainfall mixed-farming enterprises and their ability to sustainability and land degradation.

Forage shrubs serve dual purposes as they provide feed for livestock as well as environmental services. Interest in forage shrubs has increased in recent times due to concern about dryland salinity and the need for on-farm forage during repeated dry years or periods of feed shortage. Forage shrubs are not widely grown in agricultural areas, yet they are highly regarded and utilised in the extensive pastoral industry of Australia.

This review covers the following topics: the distribution of forage shrubs in the landscape, the role of forage shrubs, their economic potential and their technical potential. The review found that forage shrubs have strong prospects for use within mixed-species grazing systems, and should not be regarded as drought fodder. By providing green forage during the summer-autumn feed gap, they allow greater farm resilience and the prospect of turning off better livestock. Key research gaps for south-east Australia are to evaluate Australian forage species for use in forage mixes, anti-nutritive compounds, and to better understand livestock management and whole-farm economics with mixed-plant systems.

The importance of this report is that it brings together the available information which is of practical value to farm managers, and highlights gaps in our knowledge. It will be useful to those contemplating investment, formulating policy or considering research and development priorities for integrated farming systems including perennial shrubs. The review was conducted to inform research investment. It provided important background to “Enrich”, a fodder research project currently funded by the CRC for Plant-Based Management of Dryland Salinity, Meat and Livestock Australia, Australian Wool Innovation and JVAP. However much remains to be done and this report is pertinent as landholders and policy who are considering options to achieve more drought-resilient farming, and carbon sequestration on-farm. The review has been updated to acknowledge some recent and related JVAP projects.

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This report is an addition to RIRDC’s diverse range of over 1800 research publications. It forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems. The JVAP, under this program, is managed by RIRDC.

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Peter O’Brien

Managing Director

Rural Industries Research and Development Corporation

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Abbreviations

AAR	annual average rainfall
ANF	anti-nutritive factors
CP	crude protein
CT	condensed tannins
DDM	digestible dry matter
DM/ha	dry matter per hectare
DSE	dry (non-lactating) sheep equivalents
IVDMD	in vitro digestibility
IVND	in vitro nitrogen digestibility
MDB	Murray-Darling Basin
MPa	millipascals (measure of osmotic pressure)
N/ktex	Newtons/kilotex (force required to break a staple of given thickness)
OMSB	old man salt bush <i>Atriplex nummularia</i>
PEG	polyethylene glycol
spp.	more than one species
tDM/ha	tonnes dry matter per hectare
TDS	total dissolved solids
WUE	water use efficiency

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Executive Summary

What the report is about

This report reviews the literature and previous research, to determine the potential for integrating forage shrubs into farming enterprises in low rainfall south-eastern Australia. The report focuses on the 250–650 mm rainfall zone which encompasses the drier mixed-farming belt (grazing and cropping). The review addresses the distribution of forage shrubs, their production and environmental roles, as well as their economic potential.

Who is the report targeted at?

The report will be of particular interest to farm managers, agricultural and environmental researchers, investors and policy-makers with an interest in the role of forage shrubs in agricultural practices and the environment.

Background

In Australia, natural stands of forage shrubs have been used extensively by the pastoral industry and their use offers a guide for selecting suitable and productive species for our agricultural lands. Use of natural systems has shown that grazing management is crucial for the persistence of shrubs and their continued productivity. It is also well recognised that woody plants play a significant role in reducing or minimising the threat of dryland salinity—and forage shrubs can do this too. They have a high consumptive water use potential and are most effective in reducing recharge to the subsoil. If they are edible, there is an assumption that they have a dual role. This may not always be true and the placement of forage shrubs in agricultural systems needs to be carefully considered to maximise economic and environmental benefits. There is greater opportunity for exercising these management options in mixed-farming areas than in pastoral regions.

Aims/Objectives

The study aims to assess the current literature relating to forage shrubs, and overview the factors involved in introducing and integrating forage shrubs into low rainfall mixed-farming systems. It also aims to identify knowledge gaps and research needs.

Methods used

The authors researched the literature available, and integrated the findings to evaluate the economic and technical potential of forage shrubs, and areas where knowledge gaps exist. Part of the terms of reference was to comment on the recommendations made in a previous review on the same subject.

Results/Key findings

For any project involving the introduction of perennials, the bottom line needs to show an increase in productivity as well as in environmental and social stability. The paradigm ‘that monocultures are the most productive systems’ is questioned for low rainfall regions, especially those with highly variable rainfall. The premise is that current agricultural paradigms have little application when considering the use of forage shrubs. Vegetation comprises different plant types—annuals, perennial drought evaders and perennial drought resisters, each with different attributes and management needs. The authors believe landscapes that experience variable climate have greatest resilience and long-term production potential if a mixture of these plant types is present. This increased resilience and environmental stability comes from greater capacity to withstand dry periods of little production, greater certainty of production and better quality agricultural products (grain, wool or meat), resulting in higher financial returns.

Some forage shrubs, particularly saltbushes, have received mixed reports regarding their suitability as stock fodder. Much of the negative publicity has arisen from the unrealistic expectation that they can be used as a sole source of forage, often when grown on saline soils. In these situations it is unlikely that shrubs would be successful as this ration would be unbalanced or there would be excessive salt intake by the animals. Most forage shrubs have high protein contents and if managed wisely can complement other pasture to make a balanced, productive ration for livestock. Compared to conventional pastures, forage shrubs have lower production potential, but have a higher utilisation level by livestock.

A previous report listed as a minimum requirement that any new species should produce 1 tonne of edible DM/ha with a minimum digestibility of 55%. This view is challenged on the basis that the report assumed that forage shrubs are the sole feed source—a premise with which we strongly disagree. In the past, the chenopods have largely been considered as drought fodder; however it needs to be stressed that forage shrubs should not be used as a sole feed source, but rather as a regular complement to other feed types. In any case, a single species is unlikely to provide a balanced ration and therefore it will need to be integrated with other plant types.

Australia has three major groups of native plants that contain potential forage shrub species, namely acacia, saltbush and hibiscus. Acacias and saltbushes offer the greatest potential. There are many species of acacia and saltbush that warrant further investigation for their forage value, as very little systematic testing has been done particularly for those species from SE Australia. In the case of the saltbushes it is important to evaluate them for nutritive value and persistence on non-saline soils, because on highly saline soils their nutritive value is limited by excessive salt content. Other species from lesser-known genera such as *Sida* and *Abutilon* also should not be overlooked.

A number of factors may limit the prospects for introducing large numbers of new forage species. These include the presence of anti-nutritive factors and toxins as well as inherent plant attributes. Impediments to successful establishment may also eliminate otherwise valuable species. It appears that a woody superstructure and moderate palatability are important considerations in determining a plant's ability to persist in agricultural environments, even under good management. These factors need to be carefully considered in future selection work and may be the main reason why other potentially productive perennials have failed past evaluations.

The shortcomings of forage shrubs in relation to anti-nutritive factors (ANF) need to be tackled on many fronts, such as the study of rumen microbiology, the selection of plants with low concentrations of ANFs and the strategy of mixing high ANF forages with low ANF feed sources. Rumen microbiology offers the opportunity to further understand their effect on animal productivity.

There are other questions that also need to be addressed when evaluating potential species—especially plant height. Edible tree species, which quickly grow beyond bite-height, supply only limited feed as leaf fall and trees need to be lopped to make forage available. This latter option is costly and probably not cost effective under current economic conditions.

Exotic forage shrubs are viewed as more productive, but in some cases they may pose the risk of becoming weeds. Any evaluation of new exotic forage species needs to carefully consider the high risk of weediness. This is particularly so for spiny leguminous shrubs.

Other important factors that need consideration before adopting shrubs into an agricultural system include:

- layout design and optimum size of plantings on farm
- establishment costs of stands and associated infrastructure needs
- the implementation of a strict management conditions for both plants and animals.

The main economic advantage of forage shrubs comes from the ability to turn-off higher valued livestock to market. This is achieved by filling seasonal feed gaps with a high protein, green feed at a time of year when livestock on conventional pastures are losing condition. The apparent cost of forage shrub establishment is viewed by landholders as one of the major impediments to adoption. However, it should be pointed out that establishment is a capital cost to be amortised over the life of the plantation rather than an operating cost. The development of direct-drill and bare-root seedling establishment technologies are options that reduce establishment costs compared to speedlings.

There are very strong prospects for the expansion in the use of forage shrubs and trees in the low rainfall mixed-farming systems compared to other alternatives (for example biomass production or speciality products). Established markets and industry infrastructure already exist for the end products (for example lamb and wool) making widespread adoption of forage shrubs into existing mixed-farming enterprises much easier. This contrasts with other prospective new farming industries that

may take considerable time to establish as market outlets and for a stable industry infrastructure to emerge. Also new enterprises need an industry champion to promote their cause through the development phase.

The review identified several knowledge gaps regarding the use of forage shrubs and trees. These are:

- understanding of animal production requirements
- development of management protocols for the integration into existing farming systems and greater understanding of water use and competition effects
- new species evaluation to identify more adaptive, productive and nutritious species
- a greater understanding of the effect of anti-nutritive factors in forages
- economic analyses of whole-farm systems
- extension of existing knowledge.

Implications for relevant stakeholders

The major implications and outcomes of integrating forage shrubs into low rainfall mixed-farming systems are:

- an overall increase in landscape resilience
- production stability through extended feed availability and quality
- the ability to assess feed-on-hand at the onset of seasonal feed gaps
- an overall increase in feed utilisation
- the potential to change land use type
- greater certainty of product quality and quantity and reduction in management risk
- higher overall consumptive water use, reducing recharge and leakage
- a functional increase in landscape biodiversity
- increased environmental stability through stock protection and reduction in soil erosion
- increased microbiological activity in the soil.

These wide-ranging effects will impact on land managers in particular, but will have ramifications that affect the agricultural industry, the environment, policy makers and the community as a whole.

Recommendations

Further research work is required to assess forage shrubs. Our recommendations to policy makers and research funders include implementing the following actions:

- compiling species lists of potential species for each of the major landscapes
- collecting comparative data on morphology, phenology and production for potential species
- using this data to select suitable species for use in integrated mixed-farming systems
- quantifying both the economic and environmental benefits of integrating forage shrubs into mixed-farming systems
- demonstrating, at farm level, the benefits of integrated mixed-farming systems
- developing management protocols for successful species
- publishing available knowledge on suitable species
- requesting that governments consider the public environmental benefits afforded by large scale adoption and offer incentives to land users on behalf of the public.

1. Introduction

Forage trees and shrubs have been used since ancient times and have been mentioned in the bible as being used in the Old World (North Africa, India and Asia). But they are not widely cultivated in the agricultural lands of Western nations (Champion 1995). They are, however, extensively managed in the dry (arid) pastoral areas. This review will assess the economic prospects for using forage shrubs to address sustainability and land degradation within the low rainfall cereal-livestock zone of south-east Australia. For the purposes of this review, low rainfall is defined as 250 mm to 650 mm average annual rainfall (see Figure 1). The cereal-livestock zone of south-east Australia has a range of climatic conditions, ranging from a predominance of winter rainfall in the south (Mediterranean type climate), and summer rainfall dominance in the north. As a result feed shortages occur, particularly in late summer–autumn in the south. In the northern portion the feed gap usually occurs in late winter–early spring. Forage shrubs may help fill these seasonal gaps with appropriate green, high quality feed.

It is our view that current agricultural paradigms have little application when considering the use of forage shrubs, therefore an understanding of their function and management is needed before they can be successfully used. Previous reviews have dealt with the status of forage shrub utilisation in Australia and made recommendations for future development, but these reviews have been largely based on incorrect paradigms. One of the terms of reference for this study is to review previous studies, specifically that undertaken by Lefroy (2002b). It is also to focus on species suited to the Mediterranean and temperate climatic zones of south-eastern Australia. Emphasis will be placed on Australian natives such as the acacias and the saltbushes.

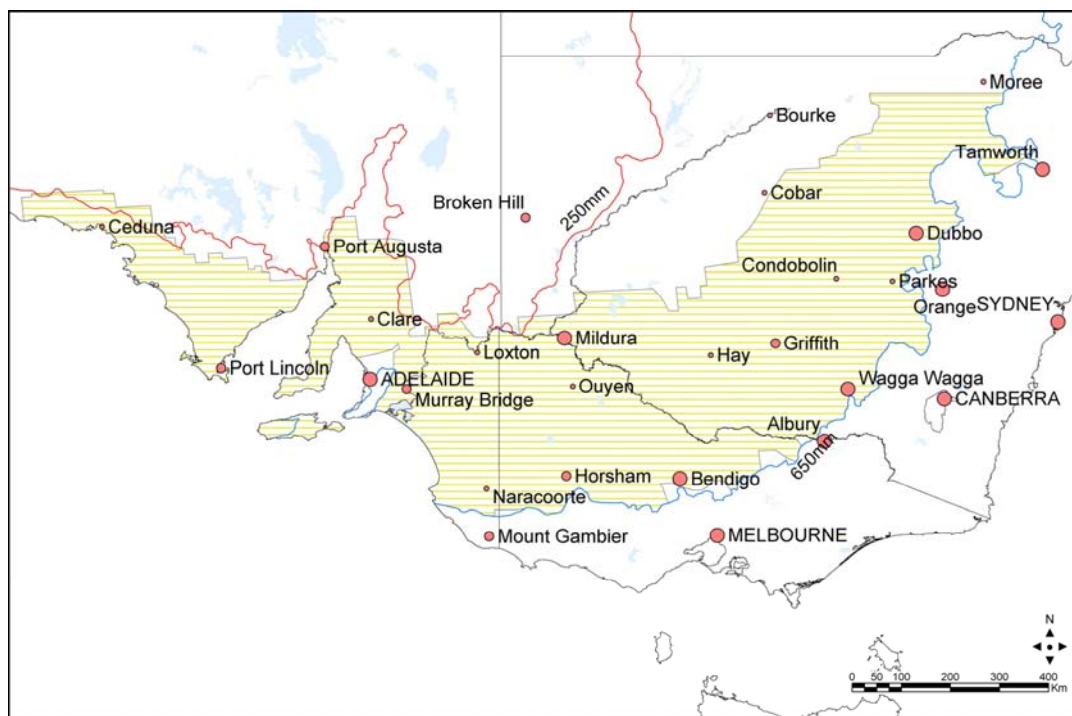


Figure 1. Map of south-east Australia showing the cereal-livestock zone = shaded area, bounded by the 250-650 mm rainfall isohyets. (source: Bennell et al. in press).

The review is organised into several chapters. The first discusses plant types, their seasonal growth and the rationale for integrating forage shrubs into grazing systems (chapter 2). This is followed by review of the use and placement of shrubs on farm (chapter 3), and livestock and environmental values of shrubs (chapter 4). Subsequent chapters consider the on-farm economic potential (chapter 5), and the plant species known to have fodder value including technical aspects of their establishment and

management (chapter 6). Final chapters summarise knowledge gaps, the approach of previous reviews, and recommendations for further research.

We have used common names through the text wherever convenient. The first time a plant is mentioned both common and botanical names will be used, but from thereon only the common name will be used. Common names follow those adopted by Cunningham et al. (1981), Jessop (1981) and Chippendale (1988).

2. An important premise to this review

– Moving from annual to perennial based farming systems

Most broadacre agriculture has been based on establishing monocultures (mostly of annual crops and some pastures) to maximise production in the belief that this will provide greatest returns. The paradigm ‘that monocultures are the most productive systems’ is questioned by the authors. This paradigm has emanated from areas with reliable and adequate rainfall. In arid areas and those with unreliable rainfall distribution there is a need to increase the proportion of perennial plants as they have the greatest capacity to best utilise total rainfall. A case for moving from annual to perennial crops and pastures in semiarid environments is strongly made by Hinman and Hinman (1992) in their book *The plight and promise of arid land agriculture*. They go on to outline potential new perennial crops, including forage plants that may be considered. When moving from annuals to perennials there is a need to understand their different behavioural patterns and what new management considerations are needed for the plants as well as the animals utilising them.

Some important considerations with regard to forage shrubs are:

1. they provide:
 - consistent green feed supply
 - quality feed (high protein)
 - improvement in utilisation of dry standing feed
 - increased permanent soil cover
 - greater overall use of soil water
2. they need controlled stock access to:
 - provide correct proportion of total feed intake
 - extend total grazing time of shrubs
 - properly manage shrub stands for optimal production
3. they have little value as:
 - mono-specific feed sources
 - ‘living haystacks’ for drought insurance
 - stock feed when planted on saline soils.

Our review and recommendations will be based on the function and management needs of forage shrubs to successfully integrate them into mixed-farming enterprises.

A basic premise of this review is the recognition of the different plant types and that we need to integrate them into our management strategies. Therefore how plant types function and how they react to management must be well understood before an assessment of their potential can be made. In the past, forage shrubs have been treated as monocultures with the perception that they are living haystacks and most valuable during drought. However, the authors believe that forage shrubs are not suited to monocultural agricultural production, rather, they should be properly managed and integrated with other plant types to achieve a more resilient and ultimately more productive system, especially in areas where plant growth is seasonal or reliant on erratic rainfall. The trick for farmers (land managers) is to fit the correct proportions of the different plant types into integrated management systems to give both continuous supply and quality feed to animals.

A brief summary of the main plant types and their characteristics follows.

2.1 Plant types

Plants fall are either annuals or perennials, depending how quickly they complete their lifecycle and/or their longevity. The perennials are further subdivided depending on their method of surviving periods of water stress (Milthorpe 1972, 1973).

2.1.1 Annuals

These are characterised by their ability to grow quickly and set seed in one growing season. They rely on their ability to have an abundant seed set and to evade drought by persisting in the seed form through inhospitable seasonal conditions. They are shallow rooted, but have a great capacity to quickly utilise freely available nutrients and water in the top layers of the soil. They are sometimes referred to as ephemerals. Relatively short periods of moisture stress can result in major disruption of growth. The water they use is used effectively, but a significant amount of the total water remains unused, ultimately leading to leakage from the profile. These attributes make them ideal for short-cycle agricultural production and mankind has exploited these attributes to the point that now most agricultural production is based on annual plants; horticulture is the most notable exception.

2.1.2 Perennials

These are plants that are usually slow to establish and may not mature sexually in the first year. Their ability to set seed once they mature is often not great and is reliant on above-average seasonal climatic conditions. Some however, have the capacity to clone or reproduce vegetatively and rely on this in preference to seeding for propagation. They also possess other attributes that allow them to grow in and survive inhospitable climatic periods. There are two main ways this is achieved, by evading drought or resisting it.

Drought-evading plants

These survive water stress by restricting water use that is, by reducing photosynthetic area through shedding and die-back of leaf material. For example, perennial grasses die back to a butt or tussock, where the rigid stems help protect the crown of the plant and they remain in that form (unless severely grazed), until adequate soil moisture levels return to permit new growth. During stress periods, forbs within this group, such as lucerne, shed all leaves and progressively die back to a basal crown of somewhat woody material, with growth recommencing as new shoots after the period of dormancy. They are moderately deep-rooted and have slightly better water extractive powers than annuals. This group of plants are relatively common in the pastoral zones (both wet and arid) where their management is well understood, but are less common in the cropping zone.

Drought-resisting plants

These survive water stress periods by toughing it out during the stress period. They restrict water use by shedding some leaf material and by reducing transpiration of retained leaves by stomata closure. They often have specially adapted leaves which restrict water loss. Other attributes such as deep-rooting ability, woody tissue and the ability to adjust sap osmotic potential assist them in combating stress periods. These attributes allow plants, at times of stress, to extract very small amounts of water from a large volume of soil on a daily basis to survive. It is important to maintain a certain proportion of leaf on the plant in order for them to control their physiological activities.

A summary of the attributes for each of the three plant types is included (Table 1) for quick reference by the reader as these attributes are important when assessing the role of different plants.

Table 1. Comparison of annuals and perennials and their basic attributes

	<i>Annuals</i>	<i>Perennials</i>	
Attributes	Drought avoiders	Drought evaders	Drought resisters
Life cycle	Complete in one growing season.	Live for more than one year	Live for more than one year
Growth rates	Grow quickly	Slow to establish but once mature, growth will recommence quickly after dormancy with new shoots.	Slow to establish but once mature, growth will recommence after dormancy with new shoots.
Reproduction	Set seed in one growing season	May not reach sexual maturity in first year. Upon maturity, ability to set seed is not great and dependant on climatic conditions. May reproduce vegetatively.	May not reach sexual maturity in first year. Upon maturity, ability to set seed is not great and dependant on climatic conditions. May reproduce vegetatively.
Root depth	Shallow-rooted	Moderately deep-rooted	Deep-rooted
Drought survival Mechanisms	Survive in seed form through inhospitable conditions. Germinate when suitable rainfall occurs. Short periods of water stress can result in major disruption to growth.	Restrict water use by reducing photosynthetic area through shedding and die-back of leaf material.	Tolerate water stress periods. Restrict water use by shedding some leaf material and reducing transpiration by closing stomata on leaf surfaces. Often have specially adapted leaf surfaces. Can adjust sap osmotic pressure to assist in combating stress periods
Ability to use nutrients	Capacity to quickly utilise freely available nutrients and water in the top layers of soil.	Variable	Variable – usually slow
Water use	Effectively use water while growing, but not all water available which results in leakage from the profile.	Slightly better water extracting powers than annuals	Extract small amount of water from a very large area on a daily basis.
<i>Conversion efficiency (WUE)</i>	High	Medium	Low
<i>Consumptive use (% of annual rainfall used by plant)</i>	Low	Medium	High
Physiology	Fleshy plants that flower, set seed and then die in one season	Form a perennial root mass and rigid stems that can die back or drop leaves to a woody or resistant butt or crown. Will sprout new shoots, flower and set seed when conditions are favourable.	Mainly woody plants. Often have blue-grey foliage, specialised leaf surfaces, fine hairs, thick cuticles or specially adapted leaves.
Sample species	Wheat, barley grass, Paterson's curse, medics	Perennial grasses, lucerne, chicory	Old man saltbush, tagasaste, kurrajong, wilga

2.2 Water use and production patterns

Extensive research on the water used by plants has been undertaken. A plant's ability to use water is governed largely by its effective rooting depth and inherent mechanisms to control water uptake (for example woodiness) as well as rate of water loss from leaves (for example phyllodes, thick leaf cuticles, and lower stomata numbers). Some plants have other specialised controls that allow them to adjust their osmotic potential to enable them to use more soil water (for example absorption of salts). The three plant groups have different abilities to use water based on their extraction potential. This is illustrated in Figure 2, which is based on work by Paleg and Aspinall (1981). The greater the suction deficit (these are negative values) the more soil water that can be extracted.

Sap osmotic pressure is used as measure of the stress that the plant is under when extracting water from the soil. The more negative the sap osmotic pressure the drier the soil that the plant is extracting water from. These measurements are made twice a day, during the heat of the day for maximum stress and at dawn to assess recovery. Osmotic pressure measurements were initially developed for cool-season growing plants (winter annuals) and field capacity of the soil was found to be $(-)0.4$ MPa and wilting point about $(-)1.5$ MPa. Perennial drought evaders (depicted as summer annuals in Figure 2) are intermediate in their ability to extract water as well as the duration of time that they are active. Woody plants (xeromorphic shrubs) and those with special controls usually maintain their sap osmotic potentials above $(-)1.5$. They have the greatest capacity to extract water from the soil (both in terms of rooting depth and ability to extract more water from the soil as well as duration), and will continue to grow until their sap osmotic pressure reaches about $(-)3.5$ MPa, then remain dormant and survive to pressures of about $(-)5.0$ MPa.

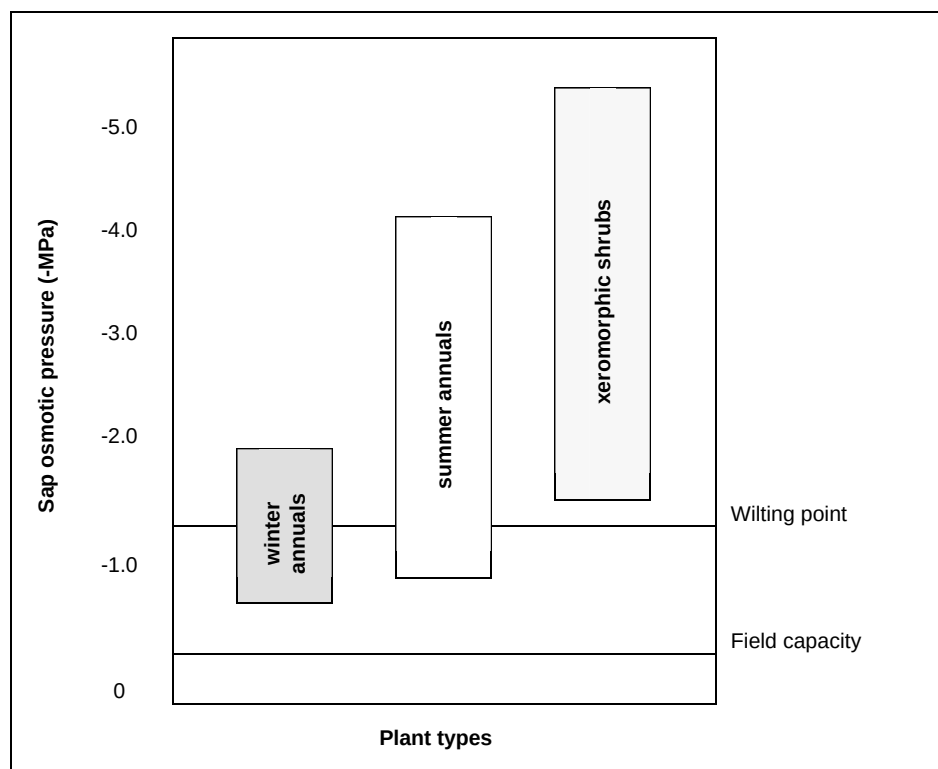


Figure 2. Diagram showing the ability of different plant groups to extract water. A greater sap suction deficit (negative osmotic pressure) indicates a greater plant capacity to draw water from the soil. Xeromorphic shrubs are woody plants with tolerance of extended dry conditions.

2.2.1 Annuals

There is no doubt that annuals have the greatest capacity to convert water to plant material. This is usually referred to as crop water use efficiency (WUE), expressed as kg DM/ha/mm of water applied. The end value is the result of numerous factors and has little to do with how much of the rainfall is actually used. Cool season growing plants experience low temperatures and high humidity, raising their relative WUE. Data collected from Wagga show that it takes three times more water to produce a kilogram of dry matter from wheat in December compared to July, due directly to the greater evaporative demand in December (N A Fettell, *pers. comm.*). Wagga is on the higher rainfall boundary of the review area. It has a long-term average rainfall of 540 mm and a yearly evaporation potential of 1600 mm. Condobolin, in the centre of the area, receives 420 mm rainfall, with no seasonal dominance of distribution. Annual evaporation potential is 2000 mm, making it a much drier environment than Wagga. This is reflected in wheat production potential where the WUE for wheat declines from about 45 to 30 kg DM/ha/mm between Wagga and Condobolin respectively.

Annual crops such as wheat approach the theoretical environmental production potential when plant density is high, complete ground cover is rapid, adequate fertiliser is supplied and fallowing ensures moisture for rapid early growth. Annual pasture production is not as efficient, for example WUE for improved pasture at Condobolin seldom exceeds 10 kg DM/ha/mm over a season. In drier environments, annual pasture growth can have similar WUEs as at Condobolin in good years, resulting in abundant forage production.

A typical growth pattern (also green feed availability) for annuals is stylised graph in Figure 3. Once plants die there is a rapid decline in their nutritive value and digestibility; this is more so for grasses than forbs.

2.2.2 Perennials

Drought-evading plants have a greater capacity for growth in warmer temperatures than the cool-season annuals, but are still capable of some growth during the colder months (Figure 3). These plants also have more extensive rooting systems than annuals and are better equipped to regulate transpiration. However, they need to persist throughout the warmer months thus requiring a maintenance supply of moisture. As a result the WUE efficiencies for this group are much lower; lucerne at Condobolin has a WUE of about 7 kg DM/ha/mm. The onset of prolonged dry periods results in initial leaf death followed by leaf fall and stem death. Feed value rapidly falls when this occurs. Perennial grasses are more persistent with the onset of drought but feed value declines in a similar manner to annual grasses.

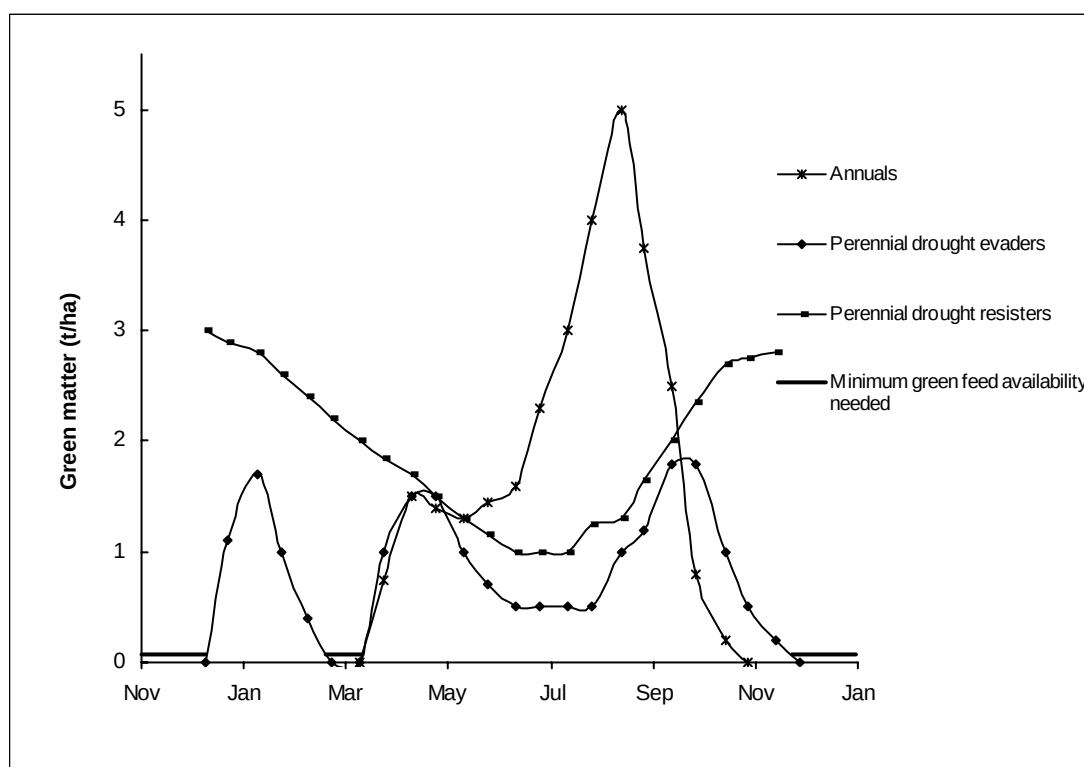


Figure 3. Stylised graph demonstrating the availability of green feed from three plant types over a typical year at Condobolin, NSW.

Trees and shrubs (drought resisting plants) that have to maintain some leaf throughout the year in order to survive, have a lower WUE than most perennial grasses and forbs, that is generally less than 5 kg DM/ha/mm (Milthorpe and Dann 1991). The only data exceeding this is from blue mallee, which is about 7 kg DM/ha/mm. This species is very aggressive in its rooting ability, and has an extensive network of shallow roots that compete with annuals for water and nutrients. Many of the perennial forage species lack this trait – hence their lower WUE.

The degree to which shrub and tree species are able to retain leaf is inherent. Tagasaste (*Chamaecystis palmensis*) readily drops a proportion of its leaf with the onset of summer drought (Milthorpe and Dann 1991) and therefore is not suited to this environment. Mulga also regulates transpiration by leaf fall during stress but because of the leaf's thickness and stability, it can be foraged by stock and not be completely lost as in the case of tagasaste. Old man saltbush (OMSB) is able to retain most of its leaf, except in severe drought, and therefore is better than most other species.

2.3 Implications for production

There were deliberate strategies implemented in some wetter shrub-steppe areas of the rangelands of southern Australia to remove the perennial shrubs, as landholders soon learnt that greater production could be achieved from annuals than perennials. While this is true for seasons with above-average rainfall years, it is different during droughts. Not only does plant production plummet, but landscape stability is severely affected by removal of the shrub cover, often resulting in severe wind erosion of the topsoil and poor pasture recovery after the drought.

It is well known that stock feeding on dry pasture do not do as well as those grazing where some shrub is present. Studies on stock grazing country with shrub showed that there was great variation in the stock diet depending on feed availability (Graetz 1986). At times the shrub component rose to 50% of the feed intake with no apparent change in wool production. Wilson and Graetz (1984) state that 'the

saltbush country of western New South Wales and South Australia has the highest clean wool cut and lambing rate of all rangelands in Australia', re-enforcing the fact that a good mix of annuals and perennials leads to sound production.

Other studies in western NSW have shown the importance of consistently having some green feed available to stock (Freudenberger et al. 1999). They have shown that when there is less than 50 kg/ha of standing green feed available to livestock, there is a rapid fall in animal live weight gain (Figure 4).

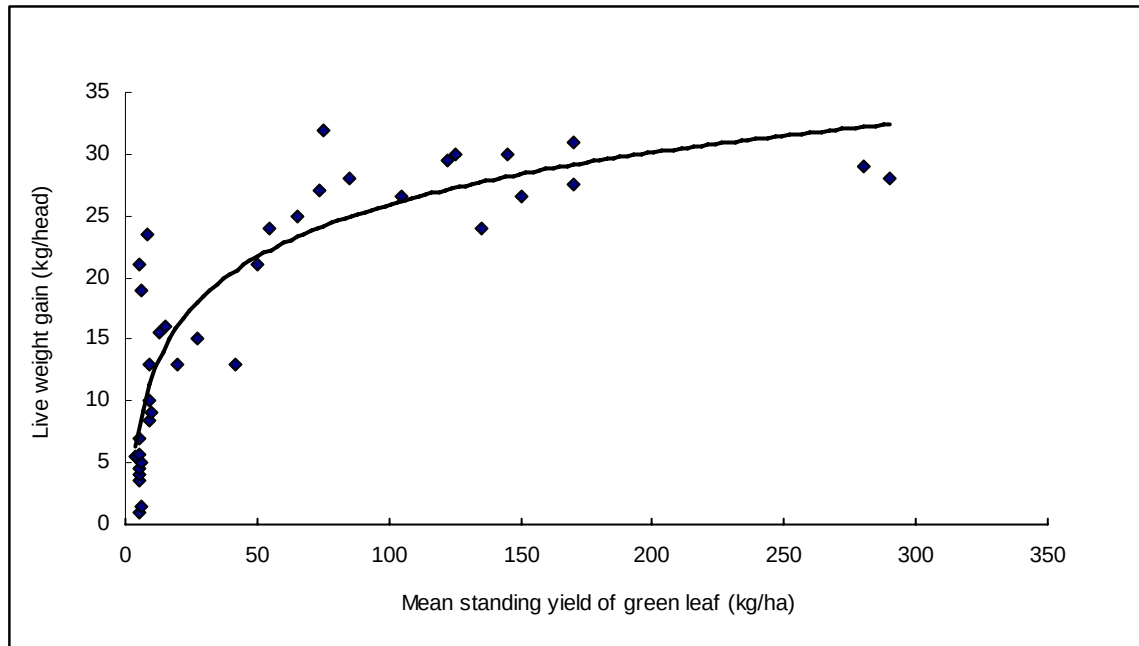


Figure 4. Livestock weight gain in relation to green feed availability. (Source: Freudenberger et al. 1999)

2.4 Management

Farm management is complex because many outcomes are controlled more by climate than by direct management (Figure 5). The operator must consider the effects of climate both on plants and animals, as well as integrate agronomy with animal husbandry to produce saleable products. Management has to consider these effects over a time span (usually 12 months) and decisions are also affected by marketing options, which are also dynamic.

Climatic variability is the most difficult to plan for and the effects of periodic extremes (floods, fire, wind squalls, severe frosts) have to be addressed. Therefore, it is important to have a diverse range of plant types as the feed source to buffer the climatic impacts.

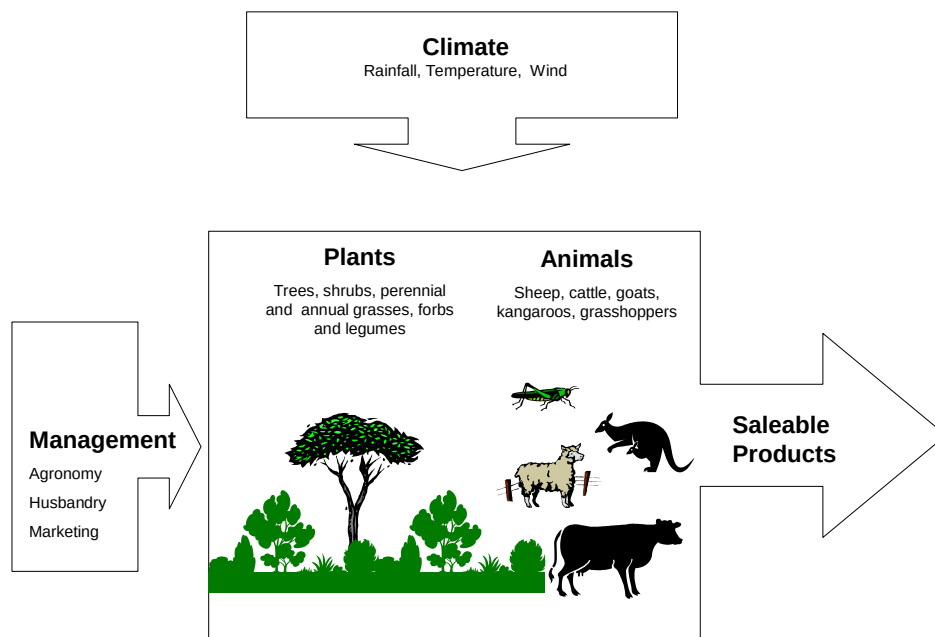


Figure 4. Schematic representation of the climatic and managerial forces that affect farm production.

Given that the growth from perennials is likely to be less than from annuals, especially in more arid environments, there has to be good reason to promote perennials other than for their role in maintaining the structural integrity of the landscape. The introduction of shrubs into the landscape offers not only increased stability, but also increased resilience in animal production due to improved feed availability and a better mix of feed to meet the animal's needs. Figure 3 illustrates when green feed is likely to be available at Condobolin.

Seasonal rainfall south and west from Condobolin becomes more winter dominant, exacerbating the lack of summer green feed availability that is likely to occur in these areas. The lack of summer rain in parts of South Australia is extreme – effective rainfall between December and March seldom occurs. Forage shrubs, such as OMSB, are best suited to provide forage to meet this green feed shortage. The trick for farmers (land managers) is to fit the correct proportions of the different plant types into integrated management systems to give both continuous supply and quality feed to animals.

2.5 Concluding remarks

Annuals provide adequate green feed from after the autumn break until the end of the spring flush, after which they rapidly dry off and lose nutritional value. Perennial drought evaders (grasses and lucerne) also provide a regular spring flush of growth, but are also capable of providing good quality green feed after summer or autumn storms. The high rainfall variability makes reliance on summer production highly risky and there can be long periods when green feed is absent. Stands of drought-resisting plants (OMSB) are able to hold spring and early summer production and this will be available to be grazed during periods that are otherwise dry. Proper shrub management has a synergetic effect, increasing the efficiency of utilisation of the dry feed (annuals and non-woody perennials) as well as supplying extra protein to the diet, to increase overall production rates.

The net result of having a mixture of all three plant types in a production system is increased resilience, over and above that which would be achieved from a monoculture. This increased resilience comes from better environmental capacity to withstand dry periods with otherwise no production, as well as higher financial returns by turning off (producing) better quality products with greater certainty.

Key points

Forage shrubs:

- offer an overall increase in landscape resilience
- offer production stability through extended feed availability and quality
- offer a functional increase in landscape biodiversity.

Land managers:

- need to consider different plant types and their function
- need to understand their water use patterns.

3. Distribution of forage shrubs in the landscape

The majority of the natural stands of forage shrubs in Australia occur in the arid areas and are used in extensive pastoral grazing enterprises. Recently, concern about the threat of dryland salinity and its potential impact, has increased interest in establishing plantation stands of forage shrubs. Shrubs have also been planted primarily for fodder purposes. In total, it is estimated that 400,000 to 500,000 hectares of fodder shrubs and trees have been planted in Australia, of which approximately 150,000 are *Leucaena* sp. in Queensland. The remainder is largely in southern Australia, comprising tagasaste, old man saltbush *Atriplex nummularia*, *Acacia saligna* and *Rhagodia preissii* (URS Forestry in press). This contrasts with an earlier estimate of approximately 200,000 ha of cultivated forage trees and shrubs in Australia (Lefroy 2002).

In pastoral areas forage has a productive role, but their value in reclamation work highlights an important environmental role that they may fulfil. This review looks at fodder shrubs' ability to fulfil either or both roles.

3.1 Agricultural systems

The greatest distinction between natural systems and agricultural systems is that in agricultural systems there is greater control and regulation of the feed source for livestock.

In low rainfall mixed farming systems various strategies have been suggested regarding the placement of forage trees and shrubs into the landscape. All strategies require careful consideration to maximise economic or environmental benefits. Several questions need to be answered:

- What will be their main role? (a provider of forage or environmental protection)
- Where will they be planted? (on recharge or discharge areas)
- What will be the planting layout? (alley, shelter-belt, scattered or block).

The role and the attributes (both positive and negative) of forage shrubs for low rainfall cereal-livestock farming are summarised in Table 2.

Fodder shrubs can be planted in blocks, alleys, shelterbelts or scattered throughout the paddock. Where in the landscape forage shrubs and trees are best planted will depend very strongly on their intended role. Stirzaker and Lefroy (1997) reviewed alley farming in Australia and made mention of alley systems using forage shrubs for timber, wind protection and soil improvement. Over half (approximately 5000 ha) of the alley plantings were made to control rising water tables; the majority of these plantings were in Western Australia. Stirzaker and Lefroy (1997) summarised the main issues facing research and development of agroforestry in general. The key ones are the need to

- identify the most profitable trees,
- plant the right proportion of the landscape in the optimal places, and
- plant with the least disruption to annual-based farming systems.

This section discusses planting arrangements and use of shrubs on farm.

Garrett (1993) recommends a density of 200–400 trees/ha on high recharge areas with low productivity for salinity control. Low density (20 trees/ha) trees can be used on steep but productive sloping land. There are advantages in planting in a block or shelterbelt on the edge of the paddock; this minimises fencing costs and can be used for multiple purposes (Lay 1987).

Some researchers suggest that agroforestry should target the least productive land, and crop yield mapping can be used as a tool to identify the unproductive areas of the landscape better suited for planting of trees and shrubs (Cook 2000, Williams and Gascoigne 2003). Crop yield maps can be

converted to gross margin maps identifying those areas of the paddock which are least profitable and possibly making a loss. This is one strategy of shifting the balance toward woody perennials with the least cost to the farmer (Cook, 2000). A further advantage of identifying areas of the landscape suitable for forage shrubs (block or alley plantings) is to separate and manage the farm according to land class (Murray Mallee Local Action Plan 2003). This potentially allows all land uses to be re-appraised and targeted to the most appropriate land classes. For example Lamont (1998) identified old man saltbush (OMSB) as the best forage shrub option at this stage for the upper Eyre Peninsula of South Australia, as it is best utilised on the unproductive soils (such as on infertile sands, magnesite soils and shallow rocky soils) where, at best, crop production is marginal.

Rainfall restrictions also apply. Milthorpe et al. (2001) stated that plantations of saltbush should not be considered economic in areas which receive less than 300 mm annual rainfall, as production from plantations in these environments will be low and is unlikely to lead to the recovery of establishment costs.

Table 2. Positive and negative attributes that need to be considered when planning to establish forage shrubs (eg. saltbush). (Source: Milthorpe et al. 2001)

Consideration	Positive attributes	Negative attributes
<i>Environmental</i>	• permanent planting • deep-rooted • ideal plant for dryland salinity control • wind protection • sink for carbon sequestration	• cool temperature dormancy • acid soil intolerant • unsuited to waterlogged soils • may provide harbour for rabbits
<i>Stock Management</i>	• provide year-round feed • reliable supply • feed not wasted or fouled • high protein • able to turn off high quality product • not favoured by feral animals	• slow growth • moderate digestibility • needs high energy supplement • animals need to be trained • needs good quality water • potential Ca:Na imbalance in stock
<i>Plantation Management</i>	• able to access feed on hand • fills seasonal gaps very well • cleaner, head-up grazing—fewer worms • offers management flexibility in stock type • used as tool (respite) to improve other paddocks	• ties up land from other uses • expensive to establish • needs good management • cannot handle pasture competition • needs fertiliser • high Na, N and oxalate content in feed • needs a high quality (value) product to be economic

In South Africa, alley farming systems using OMSB have been deployed very successfully (Lefroy 1995). South African farmers in the Klipfontein region face two major problems, the shortage of feed from February onwards until opening seasonal rains and soil erosion on light textured arable sands caused by strong westerly winds. Similar issues occur in Australia. Dale (1998) reported on a property in the Victorian mallee where Anthony Sheldon introduced organic farming practices into broad-acre farming and is using forage shrubs and alley farming. Anthony Sheldon's main incentives for planting forage shrubs were to provide forage, shelter, prevent soil erosion and reduce water evaporation. Sand hills are no longer cultivated for cropping. These areas are reserved for sheep and have been planted with rows of acacia, river saltbush and OMSB at 20 m intervals. Revegetated dune areas are estimated to provide the equivalent of 2000 bales of hay every 4 months (total area of property 1000 hectares). Between the rows other perennials such as lucerne, evening primrose and clovers have been encouraged. Paddock sizes have been reduced and nearly every fence line has been planted up with shrubs.

The largest example of alley farming in SA is on the property of Henry Angus at Meningie, which receives 400 mm average annual rainfall (Stirzaker and Lefroy 1997). On this property a mixed planting of orange wattle (*Acacia saligna*) and tagasaste (*Chamaecytisus palmensis*) was established in 30 m wide alleys. The inter-rows were established with lucerne. The main role of the alley plantings was for wind protection and forage was a secondary role. However, under the high grazing pressure the tagasaste was being selectively grazed out. Further, they described results of a survey conducted by the Roseworthy campus, University of Adelaide in 1995 where they found that 1200 ha of alley farming and forage shrubs had been established in SA. This information came from 45 farmers who responded to the survey. Twenty-two farmers indicated they had specifically planted for forage supply, and 19 farmers to control salinity. The main shrub and tree species used were *Atriplex* spp. (26 farmers), tagasaste (25 farmers), *Acacia* spp. (18 farmers) and *Eucalyptus* spp. (15 farmers). In 13 cases, the inter-row area was used for cropping and in 32 cases for pasture production.

In Victoria the main area of interest is around Horsham (Stirzaker and Lefroy 1995), where a small number of properties have established windbreaks, 150–200 m apart, of mixed species (*Eucalyptus*, *Acacia* and *Casuarina*). Near the SA border, small plantings of OMSB and tagasaste have been made. According to Andrews (1998), this agroforestry practice is the only alternative to pasture and grasses for sustainability.

The feasibility and profitability of agroforestry systems designed to manage rising, saline water tables was discussed by Lefroy and Stirzaker (1999). They concluded that in most situations trees would need to be planted over a wide and significant proportion of the landscape to manage deep drainage and salinity. Forage shrubs on saline discharge areas are only part of the solution for salinity management. Other mechanisms are needed to flush accumulated salts away from the soil profile. There are three ways in which perennial vegetation can be integrated into the farming system; segregate, integrate and rotate (Oliver et al. 2005). Segregation of trees is to set land aside for environmental services and continue to manage the best land for production. The main reason for integration (eg. alley plantings) is to increase the likelihood of capturing the available resources. Rotation has been practiced in some dryland regions using lucerne as the main plant for de-watering the soil profile. However, more recently woody native species have been advocated for use in short-term phase cropping (Yunusa and Newton 2003). They advocate this because lucerne is not adapted to acidic or heavy clay subsoils that are common in southern cropping regions of SA and WA.

Some research results on alley farming systems in low rainfall areas suggest the leakiest portion of the landscape should be targeted with full coverage of perennial vegetation rather than widely spaced belts (Knight et al. 2002). The least leaky landscapes could then continue to be cropped. However, the report by Kingwell et al. (2003) concluded that small areas on a farm sown to lucerne or other deep rooted perennial species (eg. tagasaste) are unlikely to have a significant impact on the salinity problem. The economic optimum area on a farm planted to deep rooted perennials was considered to delay the appearance of salinity, but not be enough to prevent salinity. In some places, the area of the farm that needs to be planted to have a significant impact on salinity control, may not be profitable to implement. Engineering and tree-based options are also required. Nevertheless, Kingwell et al. (2003) stated that for the short to medium term, perennial forage species appear to offer the best option for managing salinity whilst providing an increase in farm profit.

3.2 Natural rangeland systems

The study of natural rangeland systems offers a guide as to what forage shrub species may be suited to productive agricultural systems and where and how they could be grown. In natural systems the response of forage shrubs to grazing and the influence (competition and complementary effects) they have on surrounding plant species will have some bearing on how they will behave in agricultural systems. Grazing management guidelines can also be derived from natural systems.

Seedling recruitment

Early observations and studies of rangelands have already indicated that new seedling recruitments and sowings need strategic protection from livestock for successful establishment. Everist et al. (1958) noted it was impossible to establish young mulga (*Acacia aneura*) from seed in areas that are continuously stocked by sheep. Milthorpe (1978) found that the most critical time for plant survival in ungrazed stands was in the seedling stage for a period of up to nine months from germination, after which most plants survived for at least 25 years.

Grazing intensity

In native plant communities, many shrubs are preferentially grazed and are useful as indicator plants for appropriate grazing management (Shealan 1998). High stocking rates for prolonged periods can kill established shrubs of bladder saltbush (*Atriplex vesicaria*); even at the low stocking rates only 2% of bushes survived (Leigh and Wilson 1969). Watson et al. (1997) studied the demography of two long-lived arid zone shrubs, *Eremophila maitlandii* and *Eremophila forrestii*. Mortality, recruitment and size change were recorded; conditions included prolonged drought and one year of above-normal rainfall. Recruitment and mortality was observed for both species in all years. High recruitment was observed during the wet year and the two following years. Mortality was high in the two years following the year of lowest rainfall. Stocking rate had no influence on the mortality rate of the unpalatable *E. forrestii*, however the mortality rate was greater under high stocking rates for the palatable *E. maitlandii*. Low rainfall and high stocking rates had an additive effect on mortality.

Investigations in the Sahel region of Africa found that over-grazing of woody forage species was the major problem compared to that of periodic dry periods (Billie 1978). The type of stock grazing can result in different botanical composition in natural rangeland systems; for example buckbush (*Salsola kali*), spiny *Sclerolaena* spp. and mulga become more obvious under cattle grazing (Wilson 1978). Le Houerou (2000) also recognised the importance of grazing pressure in natural stands of forage shrubs in northern Africa. Grazing pressure exerts a very strong selection pressure which is counterproductive; heavily browsed individuals tend to disappear from populations or they do not get the opportunity to produce seed. However, he concluded that one could use clones from heavily grazed individual shrubs found in nature.

Plant competition

From the study of natural systems we can gain an insight into complementary or competition effects between different plant species growing together. This may provide clues as to which plant combinations may work in agroforestry systems. Complementary growth among species was found by Facelli and Brock (2000) who studied the natural open woodlands of South Australia. There they found several species of plant that are restricted to growing under the canopy environment of the long-lived tree *Acacia papyrocarpa*. In a glasshouse experiment, ruby saltbush (*Enchylaena tomentosa*) established and grew better in soil from under tree canopies than soil away from the canopy. Furthermore, after the death of trees, the under-canopy species disappeared quickly and the resultant patches were soon colonised by invasive annual species and short lived perennials. In contrast, Barritt and Facelli (2001) found the density of herbaceous plants inside *Casuarina pauper* groves was less than in adjacent open areas. This was found to be due primarily to allelopathic effects. Allelopathic chemicals were also found to influence the distribution of chenopod shrub species in the semi-arid lands of Western Australia (Jefferson and Pennacchio 2003). Allelopathy may play an important role in natural systems, but in agricultural systems the competition for water and light are most likely to have the greatest impact on growth.

A survey by Facelli and Temby (2002) of a chenopod shrubland in South Australia showed both complementary and competition effects between bladder saltbush and pearl bluebush (*Maireana sedifolia*) with annual plant species. They demonstrated that the soil seed bank of annual species was different under bladder saltbush and pearl bluebush compared with open spaces. In addition, soil under bladder saltbush had higher total nitrogen compared to open space soil. In contrast, the soil under pearl bluebush had lower available phosphorus than open space soil. Annual plant densities were higher under bladder saltbush than in open spaces, however the removal of shrubs resulted in

increased densities of annuals implying that shrub canopies inhibit annual plants in the system. The severing of lateral roots from shrubs by trenching adjacent open spaces resulted in a surprising result—a decrease in the annual plant population. It was hypothesised that water moves laterally through the shrub roots, similar to an hydraulic lift that increased the availability of water for annual plants. Vertebrate grazers were excluded and this had a dramatic affect on annual plant biomass in open spaces. It was concluded that pearl bluebush was protecting annual plants from grazing. Results show that shrubs can have simultaneous effects that compete with or promote the annual plant community through different mechanisms. Of great importance is that different species of shrub had different effects. This may provide a mechanism by which annuals and shrubs can co-exist. Facelli and Temby (2002) concluded that shrubs affect soil conditions, reduce the seed bank and growth of annual species, and modify the grazing pattern of large vertebrates.

Farm layout

Proximity to water-points, the size of paddocks, the age of paddocks and the stocking rate can have strong influences on the distribution of forage shrub species in pastoral lands. Positioning of water points, paddock size and stocking rate are also likely to have strong influences in agroforestry systems. Landsberg et al. (1999) found in piosphere studies that the proximity to water had major influences on species composition (plants, invertebrates, birds and mammals). Heavy grazing pressure close to watering points encouraged the establishment of ‘increaser’ species (annual or unpalatable shrubs). In contrast, ‘decreaser’ species (regarded as being more palatable) increased in numbers with increasing distance from water. There was a third group of plants that appeared to be unaffected by the proximity to water. A similar study by Heshmatti et al. (2002) in the chenopod shrubland of South Australia has shown that mealy saltbush (*Rhagodia parabolica*) and the less palatable black bluebush (*Maireana pyramidata*) and bitter saltbush (*Atriplex stipitata*) were correlated positively with proximity to water points, duration of stocking and stocking rate. However, they were negatively correlated to paddock size. Species such as spiny goosefoot (*Rhagodia ulicina*) and the more palatable pearl bluebush were correlated with increasing distance from water points and paddock size and negatively correlated with duration of stocking and stocking rates. The results imply that a combination of factors may be affecting the distribution of some chenopods species in fenced paddocks. Long-term grazing at 6ha/sheep may maintain forage species but may not preserve biodiversity.

3.3 Concluding remarks

The selection of forage shrub species for agroforestry systems will need to consider competition effects (eg. for water and light). Forage shrubs are resilient (e.g. drought survival) in natural stands; however over-grazing is detrimental to their long-term persistence. Grazing strategies that benefit both livestock and the plant will need to be developed, including optimal planting densities and where they are to be planted in the landscape. Because of their resilience, forage shrubs would be ideal for low rainfall agroforestry systems, particularly in regions that experience erratic rainfall patterns. Where forage shrubs will be grown in the agricultural landscape will depend on their use. When used for forage production, layout and planting design will vary from farm to farm depending on existing subdivision and watering points.

If environmental protection is important, plantings will need to be made on recharge areas to curb the salinity problem, as well as on affected areas to reclaim them. Shrubs planted in the first mentioned role may have a dual purpose as they can be grazed profitably, but it is unlikely that those planted to reclaim soil will have a productive role.

Key points

Forage shrubs:

- offer the potential to change land-use type
- offer increased landscape resilience by introducing shrubs (perennials)
- can be used for forage, wind protection and salinity management
- may not be economic where rainfall is very low, e.g. less than 300 mm
- can be planted on unproductive land together with annuals and forbs for grazing
- can assist with salinity management, but may not economically achieve whole farm salinity control where large areas of dryland salinity exist
- may have different effects on survival and grazing intensity of adjacent pasture species, depending on the shrub species
- will be affected by proximity to water points, size of paddocks, paddock age and stocking rate, which affect relative species survival and distribution

Land managers:

- need to use added management for plantation and stock, including proximity to water points, size of paddocks, paddock age, stocking rate
- need to make the distinction made between saline and non-saline production.

4. Role and value of forage shrubs

Forage shrubs and trees can have a dual purpose; they have the potential to provide forage for livestock and to provide environmental benefits to the landscape (eg. groundwater recharge, erosion control, provision of shelter for crops and livestock). However there is greater potential for uptake by landholders if there are positive economic returns from their utilisation. It is important for the reader to consider what the role of the plantation will be, whether for production or for environmental protection, or both. This section reviews the research on livestock response to shrub diets, and other farm benefits of integrating shrubs into the enterprise.

4.1 Livestock production

4.1.1 Response to feed supply

Australia

Mulga (*Acacia aneura*) is one of the most prominent Australian forage trees. Early information from Everist et al. (1958) describe mulga as rich in crude protein, high in lime, low in phosphorus and energy with just enough energy to maintain sheep during drought conditions. *Leucaena* (*Leucaena leucocephala*) and tagasaste (*Chamaecytisus palmensis*) are the only two examples of forage shrubs in Australia quoted as a sole source of feed for extended periods (Lefroy 1994). It is now clearly apparent that forage trees and shrubs as a sole source of feed do not provide all the requirements for livestock, but are best suited when used as a complement to other feed sources.

In mediterranean environments, animal performance is strongly influenced by seasonal production, with increases in liveweight during winter and spring, and decreases during late summer into autumn. Deficiency in forage quantity and quality during this period is a major problem for animal production, especially if it coincides with late gestation or early lactation (Atiq-ur-Rehman 2002). Methods of grazing should be beneficial to both livestock and plants; forage could be used to complement poor plant quality or quantity and this is far better than continuous grazing (Launchbaugh et al. 1978). The incorporation of forage trees and shrubs can have benefits to livestock production as outlined by Atta-Krah (1993):

- effect on feed quantity and availability: forage trees and shrubs should be seen as a component of pastures and considered as a component of long-term forage development
- effect on quality: by raising protein levels of the diet
- effect on feed intake and digestibility: by improving the overall digestibility of feed
- effect on animal production: by increasing survival and production.

However, there is conflict in the literature regarding animal performance from forage trees and shrubs, particularly those studies associated with saltbush. Some of the difference relates to whether the diet was solely saltbush or shrubs, and whether carbohydrate and protein sources were provided in combination.

Wilson (1966) found that sheep bodyweight was maintained for three weeks when fed a diet of old man saltbush (*Atriplex nummularia*) and bladder saltbush (*A. vesicaria*) when sheep were provided plenty of fresh water. Leigh (1972) reported reduced weight loss from sheep fed old man saltbush (OMSB) and bladder saltbush when provided as a supplement to protein-deficient diets. He later concluded the presence of chenopod shrubs in rangelands had very little influence on seasonal fluctuations of animal production, and he considered them to be of little economic value in perennial grasslands.

The live-weight changes and the effect on wool growth of sheep grazing saltbush established on saline soils have been reported by Morcombe et al. (1993). Merino wethers (adults) maintained live-weight for 28–35 days when they grazed the saltbush. Wool growth of sheep grazing saltbush at

15 sheep/ha was comparable to wool growth of sheep grazing green pasture. However, increased stocking densities resulted in decreased wool growth. Later, Morcombe et al. (1996) measured wool strength in a series of stocking density trials of sheep grazing saltbush grown on saline land. The high stocking density of 30 sheep/ha (17.2 N/ktex) resulted in lower wool strength than those sheep grazing at 25 sheep/ha (24.9 N/ktex). Those grazing at 15 and 20 sheep/ha (27.1 N/ktex) had the strongest wool. Despite the saltbush having relatively high nutritional value (70% Digestible Dry Matter, DDM and 9% Crude Protein, CP), the sheep began to lose weight soon after introduction to the saltbush. No comment is made here on the quality of the diet (low energy and high salt) (Refer to section 6.1.2.).

The findings of a forage shrub workshop conducted at Condobolin in 1997 and attended by researchers, landholders and other interested industry personnel strongly advocated that forage shrubs had limited role as a sole drought fodder and that the 'living haystack' concept was not well founded. Rather, to be useful, stands of shrubs needed to be well managed and integrated into a farming system (Milthorpe et al. 1998).

Warren and Casson (1993) found sheep that were fed hay+saltbush (equal proportions) had double the feed intake and gained weight (70 g/day) when compared to sheep on hay alone or saltbush only. Saltbush acted as a supplement to the low quality hay. It was concluded that saltbush could be used as a supplement to volunteer grasses, weeds and crop stubbles that are low in crude protein. However, later Warren and Casson (1996) concluded from four years of grazing studies in WA that sheep productivity is poor on saltbush pastures with no differences in the value of the saltbush species examined. Live-weight gains that were measured on sheep grazing saltbush were attributed to higher water intakes. They also stated that saltbush samples from non-saline lands are high in ash (>15%). On saline land, ash content can vary between 20–26%. In an alley farming system consisting of orange wattle (*Acacia saligna*) and OMSB, merino lambs gained 31 g/day grazing wide alleys, and 63 g/day on narrow alleys, compared to a loss of 50 g/day for sheep grazing only stubble (Knight 1999). This was an unexpected result because the forage shrub belts yielded less dry matter than the grain and crop stubble residues. It was thought this was due to either the availability of medics (*Medicago* spp.) and weed residues found between the shrubs, or to the shrubs themselves. Furthermore, stock may have benefited from the shade and shelter the shrub belts provided in alley paddocks.

In terms of meat quality, Hopkins and Nicolson (1999) found no difference in meat quality from eight-month old lambs fed mostly old man saltbush+pasture hay or oat grain compared with those fed predominantly lucerne. In addition, hot carcass weight of saltbush lambs was significantly lighter. It was concluded that the feeding of lambs with saltbush with pasture hay or with grain should not affect meat quality and offers a strategy for increasing animal productivity from saltbush. More recent research has also shown no detrimental meat quality effects of lambs fed saltbush+barley compared to lupins+barley+oaten hay and a control diet of lupins+barley+oaten hay+salt when fed for 10 weeks prior to slaughter (Pearce 2002).

Milthorpe et al. (2001) concluded that animal production from saltbush studies is difficult to interpret due to the fact that early work was primarily concerned with saltbush being used as a drought ration and not for production, and that later research had been targeted at saltbush grown on highly saline sites and this makes interpretation of animal productivity difficult. Lamont (1998) also questions the research that has cast doubt on the value of saltbush as a useful feed, particularly from WA where their research has shown that sheep lose condition and drink more water to overcome high salt content. Her main argument is that the WA research is based on sole saltbush diets and this is different to situations where saltbush is used in conjunction with other feeds in dryland farming situations. For example, a short-term saltbush feeding trial by Roberts et al. (2002) has demonstrated complementary effects. They examined the potential of using wheat header residue as a supplement and found merino weaners fed OMSB+wheat header residue lost the least weight (49 g/day) compared with OMSB fed alone or wheat header residue fed alone (218 g/day and 192 g/day respectively).

Overseas research

Recent overseas research has confirmed the role of saltbush as a supplement rather than a sole source of feed. Ben Salem et al. (2002a) examined various combinations of supplements; it was found that a prickly pear based diet (*Opuntia ficus-indica. f inermis*) supplemented with OMSB promoted similar growth in sheep as the commonly used diet of untreated straw and ground barley grain and wheat-bran mixture. Sheep fed on cactus+saltbush treatments averaged 31.4 g/day growth, whereas sheep on cactus+urea-treated straw grew at 19.9 g/day. Cactus is seen as an emergency forage and water source. When supplemented with nitrogen via saltbush or urea-treated straw it improved the feed value of these diets and promoted sheep growth.

In a further study, Ben Salem et al (2002b), yearling lambs were fed freshly cut orange wattle foliage *ad libitum* supplemented with one of the following:

- 0.3 kg barley
- 4.5 kg freshly cut pads of cactus
- 0.3 kg barley+1.4 kg freshly cut OMSB
- 4.5 kg cactus+1.4 kg OMSB

The different supplements were compared for 80 days as the growth, digestibility and N balance were measured. Sheep on barley+saltbush gained the most weight (54 g/day). The authors concluded that acacia supplemented with cactus and saltbush could be a cost-effective solution to the diet and nutrition of sheep during dry seasons.

Acacias, especially orange wattle, meet the requirements for livestock production based on dry matter production, but digestibility is usually limiting. Degen et al. (1995) found that orange wattle (fed as a sole diet) had high crude protein content (12.5%), but intake by Awassi sheep was low; sheep lost 227 g/day and goats lost 196 g/day. Both livestock species had negative nitrogen balances. However, digestibility was higher for goats than for sheep. Further, goats are better able to handle high tannin-containing feeds. Degen et al. (1995) concluded that orange wattle cannot be used as a sole forage source for small ruminants due to low intakes and negative nitrogen balance, but may have potential as supplementary feed due to high protein content. In Egypt, El Shaer (2003) found fresh orange wattle leaves barely maintained animal liveweight, despite a crude protein level of 12.5%. Orange wattle was pre-treated (air-drying and ensiling with other feed) to see if that would increase palatability and utilisation. Palatability, intake and nutrient utilisation were increased when orange wattle was made into silage compared to fresh and air-dried acacia. Most recently, Krebs et al. (2003) based on results from three trials also came to the conclusion that orange wattle was not suitable as a sole feed source but was worth considering as a supplement.

4.1.2 Other benefits

Lefroy (1995) reported positive animal performance from saltbush, based on farmer experiences in South Africa. Frans van der Westhuizen had 12 years experience with saltbush alleys. He had noted three main advantages:

- approximate doubling of the safe carrying capacity of the property
- no supplementary feeding of maize or lucerne was needed in autumn
- that wind erosion had been almost eliminated.

Dale (1998) also reported positive benefits to livestock production based on farmer experience on the property of Anthony Sheldon, Victorian mallee. Benefits to livestock from the introduction of native forage shrubs (*Acacia* species, river saltbush and old man saltbush) include: healthier stock due to improved summer diet (green feed in summer), a noticeable drop in fly strike, reduction in the need to drench stock, improved quality of fleece due to evenness, the fleece is softer and whiter, and the micron has decreased to 17.5 micron.

Dowler (2003) in a press article reported that despite the drought of 2002 the reclaimed saltland on Wolford and Marie Parson's property near Port Vincent on the Yorke Peninsula, SA, had thrived. Sheep were considered more profitable than cropping and better for the sustainability of that

property. These examples provide valuable testimony from farmers that should not be overlooked. Farmer champions and farmer groups have played pivotal roles in the development of saltland pastures, including forage shrubs (Barrett-Lennard et al. 2003). Furthermore, Wolford and Marie Parsons have been involved in scientific experimentation on their property in collaboration with the University of Adelaide (Parsons et al. 2002 and Franklin-McEvoy 2002). Franklin-McEvoy (2002) described trials grown on saline soil that measured the performance of sheep grazing OMSB with inter-rows of pucinelia (*Pucinelia ciliata*). OMSB and dry residues of inter-row pasture was compared with different supplements such as OMSB+250 g/hd/day barley grain, OMSB+250 g/hd/day barley straw, OMSB+250 g/hd/day barley grain+250 g/hd/day barley straw. It was assumed that weight gain in the first 14 days was due to water retention, but overall sheep on OMSB+barley grain had gained significantly more live-weight over the course of 43 days grazing during autumn. It was concluded this could lead to more valuable sheep being finished for market at a time of year when livestock grazing conventional pastures are losing weight.

Another significant benefit of shrub-based forage systems is that the level of feed utilisation by livestock is considerably higher than that of more conventional pasture systems. Although the proportion of pasture lost can be significant in plantations of forage shrubs, and in most situations the total production of edible forage is decreased with the introduction of shrubs, the level of utilisation by livestock can increase (Milthorpe et al. 2001). The advantages of shrubs are that they retain their leaf for longer, have higher protein contents and remain green. In addition, the stock can utilise the foliage to near 100% because there is little or no trampling or fouling damage. Losses due to trampling and fouling of conventional pastures (grass and legumes) can be high and utilisation levels are only between 20–30% of the total production. In addition, forage shrubs make it a lot easier to determine the level of feed on-hand before the onset of seasonal shortage.

Milthorpe et al. (2001) analysis found that, economically, landholders could benefit from the introduction of bare rooted plantings on 2.5% of the property relative to the current strategy of feeding grain during dry times. However, more assessment is required on the optimum area of forage shrubs. In addition, forage shrub paddocks can also be used to spell other paddocks at critical times of the year (eg. flowering and seeding) and this could result in better composition of pasture paddocks.

Drought feed?

In general it should be concluded that forage shrubs and trees are best used as a complement to the feed ration, but how do they rate for drought feed? The consensus from the literature is that forage shrubs and trees cannot sustain livestock throughout prolonged droughts. This was recognised by Leigh and Wilson (1969) who concluded that chenopod shrubs were of limited value for drought feed; cotton bush (*Maireana aphylla*) gave no response; bladder saltbush gave some increases in animal production but this could not be sustained for the long-term; and OMSB only provided a short respite from the pressures of drought. It was concluded that the failure of these species was due to insufficient feed because of slow growth and regrowth, and not due to nutrient deficiencies. Finally they concluded that shrubs should not be considered to have an important role in drought mitigation until more studies have been done on animal production based on different shrub densities compared to areas without shrubs. Wilson (1992) on the other hand advocates the planting up of roadsides with forage shrubs, so these areas can be used as a drought reserve. More recently, Milthorpe et al. (2001) stated that forage shrubs (saltbush) are ideal for filling short-term seasonal shortages but could not be expected to meet the feed requirements throughout a drought.

4.1.3 Nutritive value and anti-nutritive factors

Despite the relatively high crude protein contents found in many forage trees/shrubs, anti-nutritive factors (ANF) profoundly limit their nutritive value. Aganga and Tahwenyane (2003) describe the main ANFs in tree forage and shrubs that are known to limit utilisation and animal production. They are non-protein amino acids, glycosides, phytohemagglutinins, polyphenolics, alkaloids, triterpenes and oxalic acid. In addition, there are two main classes of tannins: hydrolyzable tannins and condensed tannins (CT). Both types tend to be present in trees and shrubs. Both types also differ in their nutritional and toxic effects. Condensed tannins are commonly found in leguminous forages and seeds. There is general agreement in the literature (Brooker 2000, Dynes and Schlink 2002, Aganga and Tahwenyane 2003 and Rubanza et al. 2003) that the most suitable method of reducing the impact of ANF is to mix the high ANF feed (especially high tannin feeds) with low or no ANF feed sources, in other words to use them as a supplement. The primary aim is to dilute the effect of the ANF.

Acacia and saltbush both contain ANF; in the case of the acacias, it is primarily the tannins; and for the saltbushes it is the oxalates and high salt content particularly if growing in saline sites. Native acacias are generally lower in crude protein and phosphorus and have lower digestibilities, when compared to the common African species (Fagg and Stewart 1994). Most Australian species are not considered to have high forage potential (Turnbull, 1986 cited in Fagg and Stewart *op cit*). To date, species with potential include orange wattle *A. saligna*, *A. neriifolia*, *A. pachycarpa*, cooba (*A. salicina*) and OMSB.

Protein is the major nutrient that influences grazing animal productivity. Kumar (1983) found that the tannin content of acacias, combined with their protein-precipitating capacity, reflects on crude protein in a negative relationship. Also some acacias have toxic potential depending on the presence of cyanogens and hydrolysing enzymes which liberate hydrogen cyanide from the cyanogens (Fagg and Stewart 1994). In addition, significant amounts of non-protein nitrogen (betaines and nitrates) can be found in salt tolerant plants such as saltbush (Kelly 2002). Brooker (2000) summarised that tannin levels as high as 10–15% dry weight have significant anti-nutritional effects. Relatively low levels that do not go above 5% can be beneficial to animal production by preventing bloat, providing anthelmintic (anti-parasitic) properties and providing rumen bypass protein. The selection and breeding of forage shrubs/trees with low levels of toxin/anti-nutritive compounds has been unsuccessful to date (McSweeney et al. 2002), mostly because these compounds form an integral part of the plants' survival in tropical environments. McSweeney et al. (2002) acknowledge that research on ANFs in forage/trees has been fragmented, partly because there are a large number of secondary compounds involved and methods of identification have not been standardised.

To improve the utilisation of forage trees and shrubs a more thorough understanding of secondary compounds is required. A study in Kazakhstan (Degen et al. 2002) showed palatability of forage shrubs was primarily influenced by the total phenolic content and not by metabolizable energy, protein and fibre content. Readily-eaten plants contained 17.7 g/kg DM tannins compared to non-eaten plants with a content of 66.4 g/kg DM. In Australia, Dynes and Schlink (2002) stated the digestibility of mulga to be between 39% and 64%, suggesting that there may be scope to select more suitable lines for animal production. Krebs et al. (2003) demonstrated that as orange wattle matured, its nutritive quality decreased (eg. crude protein).

Some species have a high nutritive value and show no apparent toxicity to animals, yet they are left completely ungrazed by domestic stock. Butterfly bush (*Petalostylis labicheoides*) is a typical example (Cunningham et al. 1981, Mike Bennell pers. comm.).

Palatability and anti-nutritive compounds have not been systematically evaluated for southern Australian shrubs. A project called 'Enrich' is being funded by the Cooperative Research Centre for Plant-based Management of Dryland Salinity, Meat and Livestock Australia, Australian Wool

Innovation and the Joint Venture Agroforestry Program, to investigate a range of the most promising species in southern Australia.

Future selection of plants

The following criteria should be considered when assessing the suitability of shrubs as forage:

- nutritive value
- chemical composition
- yield
- recovery from grazing
- palatability
- growth habit.

According to Mochrie et al. (1981) it should be possible to evaluate a new forage species in 10 years. The evaluation should include animal preference trials in the early stages and the final evaluation should include assessment of animal production, economic feasibility and details on forage plant management.

To date the evidence for the nutritive value of saltbush has been ambiguous. Atiq-ur-Rehman (2002) mentions how very few pen-feeding studies of saltbush have been conducted. The author stresses the importance of detailed descriptions of trial work with saltbush so that the data generated are of value in making assessments as to the true nutritive value of saltbush. Part of the problem associated with saltbush evaluation in the past has been the over-estimation of the energy value of chenopods growing on saline soils. No distinction has been made between soluble and non-soluble ash components or assumptions were made that the soluble ash content remained constant, yet this is the component that disappears during laboratory digestion methods (Norman et al. 2002). Wilson (1977) also states that digestibility measurements used alone do not provide a good assessment of forage value; for example he found that *belah* had the lowest digestibility (29%) but sheep and goats had the highest feed intake of *belah* compared to the more digestible species OMSB and *wilga* (*Geijera parviflora*) (69% and 59 % respectively). Norman et al. (2002) state the importance of mixed swards and that chenopods are not suitable for use as the major dietary component, particularly if grown on saline soils. Mixed forage plant systems offer a better-balanced diet to livestock than monocultures (Dean Revell, pers. comm. 2004).

4.1.4 Shelter—protection for animals and crops

Studies on windbreaks provide an indication of the likely benefits from incorporating forage shrubs into agroforestry systems. Some of these benefits are shelter and the protection of crops and animals.

Some local anecdotal evidence and overseas work has indicated that shelterbelts can increase yield of certain crops grown on the leeward side of the shelter belt (Race 1993). The extent of the benefit or negative effect is usually described in units of the height (H) of the windbreak. Research at Rutherglen Research Institute, Victoria, has shown that the yield of crops on the sheltered side is greater than in unsheltered areas. There was a reduction in yield on the sheltered side for 1.5 H, but from 1.5–9 H wheat yield increased by 25% and oats by 17% on the south side and by 22% and 2% respectively on the east side of a N–S belt. In effect, the lack of production in the competitive zone was compensated. The reasons for the yield increase are unclear. Later windbreak studies were made during the 1990s through the National Windbreak Project (Sudmeyer et al. 2002, Bennell and Cleugh 2002). Generally findings for cereals were negligible gains from shelter once competition was taken into account, but pulses (lupins and faba beans) showed positive net gains.

Expected benefits of shelterbelts for livestock enterprises include improved lamb survival and reduced losses of shorn sheep (Bird 1993). Bird (1998) stated there are few reports of increased pasture production resulting from shelter; many of the results are conflicting. However, windbreaks are often grown in windy environments as a shelter for livestock and not for the shelter of pastures.

Later, Bird et al. (2002) confirmed that windbreaks had no significant effect on pasture growth in the 2–10 H shelter zone. This result was based on four years of trial work. However, windbreaks clearly had an influence on pasture growth (perennial ryegrass and subterranean clover) in the competition zone (0.5–0.75 H) at Willandra, Victoria. Growth was only 69% of the open paddock yield. At the other site, Helm View, production in the 0.7–1.0 H zone was 74% of the open yield.

Design of alleys and windbreaks is likely to influence their effectiveness. Careful consideration needs to be given to their placement because the results can be detrimental rather than beneficial. For example, Knight (1999) described a study in southern Australia where a spider web alley design was used; however this design resulted in wind tunnelling at this site in the east–west belts and crops were damaged. The predominant winds come from the west (NW and SW) so only north–south belts should have been used.

For most of Australia, wind patterns are highly variable and this may in part explain why windbreaks have had very little effect on the yield increase of crops and pastures. However, on soils susceptible to wind erosion and sandblasting of emerging crops it can mean the difference between a crop and no crop due to crop establishment failure (Cleugh et al. 2002).

One of the greatest benefits from windbreaks is the reduction in stock losses from extreme weather conditions (Johnson and Brandle 2003). Trials in south-east Australia have shown a reduction in losses of new born lambs by 50% due to the presence of shelter belts. Off-shears coupled with adverse weather conditions is a vulnerable time for sheep survival. Reports of losses of 250,000 head over a four-day period have been quoted (Johnson and Brandle 2003). The main benefits of shelterbelts are providing protection to new-born lambs and sheep off-shears, by reducing the animal's energy requirement during adverse weather conditions. However, there are situations that can negatively affect animal health, such as increased fly strike incidence in OMSB stands during hot, humid weather (Milthorpe et al. 2001).

4.2 Environmental benefits

Forage trees and shrubs are multipurpose. Not only can they provide useful forage for livestock, they can also provide environmental services. Potential benefits include reduction in wind impact and erosion (mentioned in earlier sections), and increase in biodiversity. This section concentrates on water use and recharge control. Extensive clearing of native perennial vegetation has led to high recharge levels, because Australian farming systems largely replaced the perennial native vegetation with annual crops and pastures which are not efficient water users. This led to excessive leakage to groundwater and the eventual appearance of salinity as groundwater tables rose, bringing the salt with them. Table 3 outlines the role forage shrubs (in this particular example OMSB) have in recharge (generally non-saline soils) and discharge (generally saline soils) environments.

Table 3. Some potential uses of OMSB when grown on non-saline and saline soils (source: Honeysett et al. 2004)

Attribute	Non-saline soils	Saline soils
Productive capacity	Moderate	Low
Environmental benefits	Moderate–High	High
Suited for grazing with pasture	Yes	No
Extends feed availability	High	Low
Value as sole drought fodder	Marginal	No
Management needs	Critical	Not so critical

The Mediterranean-type environment is particularly fragile (Atiq-ur-Rehman 2002). Atiq-ur-Rehman highlights two major problems associated with Mediterranean-type environments throughout the world: 1) salinity/waterlogging and 2) the destruction of natural vegetation or overcropping and

mismanagement of land resources. Many Australian mediterranean environments are similarly affected. Gates (2001) gives the example of the Coorong district in SA that has been extensively cleared of deep-rooted perennial native vegetation. Annual pastures constitute the largest land use in the Coorong district and contribute the most to recharge. It has been estimated that 76% of the recharge in the area is due to annual pastures. The Local Action Plan for the Coorong covers a total area of 700 000 hectares, with 57 000 hectares affected by salinity and a further 70 000 hectares at risk. Australia-wide, salinity is a major environmental problem. Many regions in the cropping zone of Australia are at risk of salinity or already affected. The report by Kingwell et al. (2003) lists the zones most at risk; by the year 2020 an additional 1.1million hectares of farm-land in the cropping zone is predicted to become saline. In terms of present value, the impact of the spread of salinity (year 2000–2020) in grain growing regions of Australia is estimated at \$238 million.

In his presentation at the 11th Australian Agronomy Conference, Cocks (2003) outlined that according to the National Land and Water Resources Audit 2001, Australia has 5.6 million ha of land already affected by salinity and this is expected to increase 6 fold. He also quoted ABS figures that indicate 14% of Australian farms are affected and 51% of farms in WA are affected by salinity. Furthermore, the way in which dryland salinity appears in WA is quite different to the Murray-Darling basin (MDB). In WA, groundwater flow is localised; in the MDB salinity can appear many hundreds of kilometres away from its source. In some regions such as the Victorian mallee, deep drainage takes a long time (80–100 years of cropping) to become recharge (O’Connell et al. 2003). However, long fallows are common practice in the Victorian mallee and this may increase the risk of deep drainage.

Many researchers advocate that part of the solution to salinity control is the use of perennial plants in the farming system with the aim of mimicing natural systems. Therefore, high water use by plants is viewed as a valuable attribute. The literature has many examples of high water use by perennial forage plants. Scott (1989) found trees had removed 50 mm to 150 mm more water from the soil compared with the pasture control. This was equivalent to 30% of the annual rainfall of Wongan Hills, WA. It was concluded that trees had the capacity to reduce ground water recharge. The water use efficiency of two forage species (*Acacia blakelyi* and *tagasaste*) was double that of the eucalypt species in a trial conducted by Eastham et al. (1994). They showed acacia and tagasaste had water use efficiencies (WUE) of 35 kg/ha/mm compared to the eucalypt’s level of 15 kg/ha/mm. This was attributed to the forage shrubs’ greater biomass production. It was hypothesised that because both forage species used in the trial are legumes, this could have improved nitrogen nutrition due to nitrogen fixation and this may have led to higher WUE; this has been shown in other agricultural crops. The authors concluded that any of the trees species or forage species used in the trial would be capable of reducing water tables.

Overseas research found OMSB had higher productivity, water use efficiency and consumptive water use compared to conventional forage crops found in Arizona’s irrigation districts (Glenn et al. 1998). In addition, OMSB performed well on mildly saline waste water (1149 mg /l Total Dissolved Solids [TDS]) and brackish water (4100 mg/l TDS). Later, Glenn et al. (1999) highlighted the potential for chenopods to be used to recycle saline agricultural waste water.

Barrett-Lennard and Malcolm (1999) also found saltbush used significant amounts of groundwater at Kellerberrin, WA. Approximately 60–100 mm of ground water was used at the site by the saltbushes. However, grazed OMSB was found to have poor water usage in a trial conducted by Slavich et al. (1999). That paper examined the water use of regularly grazed OMSB plantations established over shallow saline water tables (1–2 m). Transpiration rates were very low, 0.3 mm/day, and this was related to low leaf area index, low stomatal conductance and low xylem water potentials. Plants were mostly using shallow water derived from rainfall. The authors acknowledged that ungrazed bushes could have much higher transpiration and groundwater discharge rates. These results also imply that groundwater discharge would be greatest from shrubs on the margins of saline depressions.

Knight (1999) described an alley farming trial at Pallamana, SA (300 mm average annual rainfall). The primary aim of the trial was to reduce wind damage to crops but water use was measured. There were three treatments: control with no belts of trees, a wide alley with belts 75.6 m apart and narrow alley with belts 34 m apart. Belts were established with orange wattle in the middle flanked by two rows of OMSB. Water was being extracted by the shrubs at depths 250–600 cm after only 18 months following planting. Knight et al. (2002) reported in more detail the water usage by forage shrubs or trees at three sites (Pallamana, SA; Walpeup, Vic.; and Bridgewater Vic.) in the 30–450 mm rainfall zone of the Murray-Darling basin of SE Australia. The deep soil profile had dried under and adjacent to tree belts during four years of an alley farming system. Extra soil water storage (82–261 mm) capacity was created in the 2.5–6 m profile. It was estimated, based on average recharge rates (11–35 mm at Pallamana) that cropping could be conducted for 17–55 years before leakage had accumulated. It is unlikely that leakage will occur under or directly adjacent to the alley belts in this environment because the water storage difference under belts is greater than the largest episodic event probable in this region. In practice, farmers tend to space alleys 50–70 m apart; therefore only a small percentage of leakage will be controlled. Unkovich et al. (2003) also described the water usage from the same series of trials described by Knight et al. (2002). Unkovich et al. (2003) found the water use under trees at the Bridgewater site had increased with time to 243 mm greater than under crop-only treatments. At Walpeup and Pallamana shrubs had utilised stored soil water, however they only occupied 7–18% of the land area. The results from this trial work show that alley farming in low rainfall (<350 mm) environments is going to be greatly influenced by competition for water between crops and perennials.

Lucerne (*Medicago sativa*) is already used extensively for groundwater recharge control throughout Australia, but Yunusa and Newton (2003) challenge the utilisation of lucerne in this role due to some limitations. Woody plants have greater potential to use stored soil water through autumn and early winter compared to lucerne. The use of this water creates greater capacity in the soil for the storage of excess winter rainfall. In a study at Rutherglen, Yunusa and Newton (2003) demonstrated that a mixed stand of three-year old trees (*Acacia melanoxylon*, *A. dealbata*, *A. pravissima*, *Eucalyptus botryoides*, *E. camaldulensis*, *E. campaspe* and river oak [*Casuarina cunninghamiana*]) used more soil water than lucerne over an 18 month period. Woody species created a soil storage buffer of 248 mm compared to lucerne 213 mm. Simulation models predicted the recharge to ground water can be prevented within four years with woody species, and resumption of recharge could be delayed for up to 10 years. Ward (2003) used lucerne to test the model package ‘Leakage/Buffer Model’ (LeBuM). This package was used to estimate leakage and the buffer created by a perennial phase of lucerne. Leakage of soils at Moora, WA had decreased as the proportion of lucerne in the rotation increased. At Merredin, a drier site, the incorporation of a perennial phase was more effective.

4.3 Concluding remarks

Experimental evidence using saltbush as a sole diet indicates livestock may not gain weight, however mixed diet trials (e.g. hay and saltbush) have positive results. It needs to be stressed that forage shrubs should not be used as a sole feed source, but rather as a complement to other feed types. Compared to conventional pastures, forage shrubs have lower production potential, but have a higher utilisation level by livestock. Many forage shrub species contain anti-nutritive factors and some contain toxins. Therefore, selection of new species of forage shrubs will require a ‘duty of care’ in selecting those with the lowest levels of ANF and little or no toxins. The presence of ANF in current forage shrub species enforces their role as complementary feed sources and not as a sole feed supply.

Forage shrubs are ideal for agricultural systems in that they provide valuable feed for livestock and can help alleviate environmental problems such as high ground-water recharge. In addition they provide shelter for vulnerable livestock (new-born lambs and sheep off-shears) and crops (protect from sandblasting).

Key points

Forage shrubs:

- offer an overall increase in feed utilisation
- offer the ability to assess feed on-hand at the onset of seasonal feed gaps
- offer increased environmental stability through stock protection and reduction in soil erosion
- offer higher overall consumptive water use, reducing recharge and leakage

Land managers:

- need to use them with other feed-types
- should not recommend them as a sole drought fodder.

5. Economic potential

Commercial agroforestry for wood products in the low rainfall zone (400–600 mm) is unlikely to be as profitable as similar enterprises in the high rainfall zone, due to lower growth rates, less well established forestry infrastructure and greater distances to markets (Zorzetto and Chudleigh 1999). Nevertheless, those authors identified forage shrub production as having potential for the low rainfall zone. Plants with dual functions (forage production and environmental protection) will improve the commercial prospects for the low rainfall zone. Tagasaste was considered in that report to offer the greatest economic potential for increased livestock-carrying capacities throughout the drier regions of Australia. It was acknowledged that the native saltbush species also have potential as forage.

Are forage shrubs and trees profitable? Malcolm (1990) stated economic studies have shown that the use of chenopod shrubs is profitable and the sheep-carrying capacity of the whole farm is increased because feed is available during times of feed shortage (eg. late summer and autumn). Lamont (1998) and Milthorpe et al. (2001) showed no overall increase in stocking rate with the introduction of saltbush. It would appear the main economic advantage of forage shrubs and trees is to fill the late summer and autumn feed gap (Milthorpe et al. 2001, and Henschke 2001), thereby reducing the reliance on hay and grain and costs associated with hay-making, buying and maintaining fodder stores (Henschke 2001).

Further economic evaluations in WA have indicated that farmers should use recharge areas for the most profitable farm practices and plant forage shrubs on discharge areas (Malcolm 1993). It was also recommended that farmers begin planting forage shrubs on areas they are most likely to establish successfully. These areas can be used for nursery stock to widen the plantings to less suitable areas. In WA, it is estimated that the autumn feed gap can be filled with a farm vegetated to 10–15% with halophytic shrubs. Lesser value is attributed in models that include areas above 10–15%. Carrying capacity in WA was quoted at 0.5–6 DSE/ha and the value was calculated at \$93/ha/yr (based on money saved on hand feeding). Recent modelling work by the Enrich project (Marta Monjardino pers. comm.) has also found that planting 10% of the farm to shrubs was often the most economic, with lower and higher proportions of shrubs providing lower returns. This modelling is informed by surveys of shrub-managing landholders in southern Australia (Toovey and Revell, pers. comm.).

Lamont (1998) has used an economic model for saltbush in dryland farming systems in South Australia and this indicated an average gross margin increase up to 59%, based on the assumption of 5% increase in production from protection. Forage available during the summer/autumn period will have a higher relative value than during spring (Franklin-McEvoy 2002). Additional value can be attributed to forage shrub systems due to the green out-of-season (summer and autumn) feed they provide. The value of off-season feed is illustrated by Warner et al. (1998) who state ‘grazing mature crops of lupins and field peas to produce prime lambs out of season generated greater gross margins per hectare than would have been achieved had these crops been harvested for sale of grain.’

A grazing trial at Narromine, NSW (Anon. 2000) showed a gross margin for OMSB of \$382/ha compared to naturalised pasture of \$55/ha (medic and grasses). However, it was concluded that similar trials need to be replicated elsewhere with scientific rigour to add weight to the case of utilising OMSB.

One of the main impediments to growing forage shrubs and trees is the high costs associated with establishment. Lower costs have been achieved in some alley forage shrub systems with the development of direct seedling and bare-root seedlings (Stirzaker and Lefroy 1997). Economic analyses by Milthorpe et al. (2001) examined the profitability of OMSB using three different establishment techniques: direct-seeding (\$153/ha), seedlings (\$695/ha) and bare-root transplants (\$175/ha). Results of the analysis reveal that OMSB established using the bare-root technique could be financially beneficial to landholders. Direct seeding and seedlings were less desirable financially compared to the current practice of grain feeding. It was concluded that landholders could benefit

from the introduction of bare-rooted plantings on 2.5% of the property compared with the current strategy of feeding grain during dry times.

Further assessment is required on the optimum area of forage shrubs. Using a bio-economic model, O'Connell and Young (2002) found that saltland pastures are likely to be profitable over a range of scenarios with 63% of the total benefit coming from reduced supplementary feeding costs. Results from saltbush grazing trials in South Australia indicated it is economically viable to supplementary feed merino wethers with barley grain while they grazed saltbush and pastures during summer into autumn (Franklin-McEvoy 2002). Yet, Hamilton (2002) through using model simulations for South Australia found costs of establishment for integrated perennial systems generally exceeded the benefits that were received by landholders.

Kingwell et al. (2003) present an analysis of saltbush grown on non-saline land in Lachlan Shire, NSW. In the analysis it was assumed saltbush would be grazed in conjunction with stubble. A further assumption was that only 2.5% of the property area was planted to saltbush. The analysis estimated an average annual value of \$85/ha of saltbush that was not considered profitable enough to encourage adoption. However, the authors acknowledge that the profitability of saltbush was under-estimated, and the analysis did not take into account the full costs of supplementary feeding during long periods of feed shortage. Furthermore, the analysis did not consider increased returns to livestock enterprises which may be able to grow fat lambs on saltbush, allowing for them to be turned off at heavier weight.

Investment in saltland pastures will be dependant on the level of livestock income to cropping. Good prices for livestock will more likely lead to investment in rehabilitation of pasture; it will also depend on the proportion of the farm affected. Kingwell et al. (2003) also presented economic analyses that showed the value of saltbush was sensitive to the price of grain. High grain prices usually mean smaller areas of saltland pasture and less sheep on the farm. Low grain prices are indicated by higher sheep numbers on the farm and the area of saltland is correspondingly higher. However, high grain prices may also increase the profitability of growing saltbush because saltbush can be used to substitute expensive grain as a supplementary feed. A 25% increase in grain price increased the value of saltbush by 20%.

Government policy

A number of authors have stressed the importance for government incentives to help promote and increase the level of forage shrub and tree adoption. Champion (1995) was critical of the lack of government support for investment in forage shrub and tree research, and also that it did not attract any subsidies or tax concessions for farmers wishing to establish forage shrubs. He proposed governments could assist in three ways:

- develop research and planting assistance programs for forage trees
- provide subsidies and taxation deductions for planting forage trees
- introduce legislation to limit carrying capacity of each rural property to the long term sustainable limit based on a farm plan (based on potential forage reserves).

There are early examples of government incentives. In Tunisia during the 1930s, settlers had a clause in their contract stipulating that they were required to establish spineless cactus on 2% of their allotment in the early years of the occupancy (Le Houerou 2000). Ownership rights were revoked if this did not occur. Consequently, those settlers who had established cactus were least affected by the severe drought between 1946 and 1948.

Governments in Australia have become more aware of the funding requirement for forage shrub related projects because of the unceasing threat of salinity. But forage shrubs are just one of many incentives competing for funds. The Hon. R.I. Lucas outlined the government's strategy for the development of salt-tolerant sustainable agriculture in the Murray-Darling Basin (Lucas 2000). Examples included farm forestry, low rainfall plantation forestry, alley farming, lucerne and

opportunity cropping. Incentives were paid to landholders according to the net private cost and the public benefit that accrues from their on-ground works. This led to a strong uptake of land use changes. At a local government level, incentives are available. Programs such as ‘Salt to Success’ and that of the Coorong and Districts Council have provided funding to revegetate a further 912 ha with forage and product (cut flowers) vegetation (Voigt 2000). Gates (2001) describes the Coorong District Council’s long-term commitment to the management of salinity through the development of the Local Action Plan. Forage shrubs (saltbush and tagasaste) form part of the program. In 2002, on-ground work incentives paid \$125/ha for saltbush and \$40/ha for tagasaste and \$450 per km fencing. From 1996–2002, 1135 ha of saltbush was established and 1791 ha of tagasaste. However, protection of remnant vegetation and the sowing of lucerne pastures constitute the greatest percentage of on-ground work programs in the Coorong district. Threshold values generated by economic models (Hamilton 2002) give some indication of the value of non-market benefits such as reduced recharge and improved biodiversity. Threshold values may give an indication of the level of incentives needed to be offered by government to landholders for the integration of perennials. For example, the Federal Government allocated \$10 million as drought relief from the Natural Heritage Trust’s Australian Government Envirofund (Anon. 2003). These grants ranged in value from \$605 to \$27,273 for tree replanting following tree death from the drought, or to grow forage using native drought tolerant species.

5.1 Concluding remarks

The main economic advantage of forage shrubs is to fill the summer–autumn feed gap by providing high protein green feed. There is potential to turn-off heavier livestock for market from forage shrub stands at a time of year when livestock on conventional pastures are losing condition. The cost of forage shrub establishment is viewed by landholders as one of the major impediments to adoption. However, it should be pointed out that this is a capital cost rather than an operating cost. The development of direct-drill and bare-root seedling establishment technology now reduce these costs of establishment compared to using speedlings. If farmers are to adopt forage shrubs they need a clear demonstration of their economic worth plus government incentives.

Key points

Forage shrubs:

- offer greater certainty of product quality and quantity and reduction in management risk.
- fill the summer–autumn feed gap by providing high protein green feed, which is their key economic advantage.

6. Technical potential

6.1 Natives

Two main groups of plants emerged from the literature as having the most potential as native forage species in Australia, namely the acacias (wattles) and the chenopods (saltbush and bluebushes). Ironically, more *Acacia saligna* (orange wattle) and saltbush (eg. OMSB) have been planted overseas than in Australia. Other prospective species should not be ignored (e.g. see Florasearch list of fodder species, Bennell et al. in press).

6.1.1 Acacias

Acacias are a very important group of plants in the rural economies of many countries (Fagg and Stewart 1994, Midgley and Turnbull 2003). Australian acacias have been planted in 70 countries (Midgley and Turnbull 2003). Australia has 1165 native species which represents more than two-thirds of the world's acacias (Maslin et al. 2001; Maslin and McDonald 2004), yet very little is known about their forage potential, with a few exceptions. Like most forage shrubs, acacias have anti-nutritive compounds that need to be taken into consideration when utilised for stock forage. Much attention is focussed on foliage production but litter fall (foliage and pods) from acacia can be as high as 7 t/ha/yr; therefore in a selection program consideration should be given to assessing the quality of litter (Dynes and Schlink 2002). The added benefit of acacia is their ability to fix nitrogen, hence contributing to the fertility of soil.

Earlier reports (eg. Everist et al. 1958, Chippendale 1963, Stannard and Condon 1968) make reference to the use of mulga (*Acacia aneura*) for livestock feed, particularly during drought. However, many farmers considered the lopping of trees for forage such as mulga as uneconomical (Stannard and Condon 1968). Repeated lopping may kill trees, which will destroy shade, shelter and expose soil to wind erosion. Stannard and Condon (1968) mention other useful fodder species including ironwood (*Acacia excelsa*).

In 1987, Lay recommended the planting of silver mulga (*Acacia argyrophylla*) and black wattle (*Acacia decurrens*) in South Australia for forage production. Over half the species evaluated by Vercoe (1988) were acacias and in his treatment of these species he set the parameters for further research of species at digestibility >40% and protein content >10%. At this level, the forage would be not be suitable for maintenance requirements and would need some protein as a supplement. The most impressive species in terms of laboratory analysis included three *Acacia* species (*Acacia shirleyi*, *A. cowleana* and *A. hylonoma*). These three are all northern species, the last mentioned coming from the rainforests near Cairns; hence they are unlikely to be of great use in the area currently under review.

In a study by Thomson et al. (1994) 16 species of Australian acacia were identified as potentially useful forage. However, it was noted that some of these species may have toxic properties (cyanogenic glycosides, saponins, tannins and fluoroacetate). They stated that the main advantage of Australian acacia was their ability to retain leaf (phyllode) during dry seasons. However, they have low nutritive value due to the high fibre content of phyllodes. Some species (*A. cambagei*, *A. georginae*, *A. murrayana*, and *A. salicina*) have been linked to poisoning of livestock; however this is uncommon and most likely to occur if abnormally high amounts of foliage are eaten.

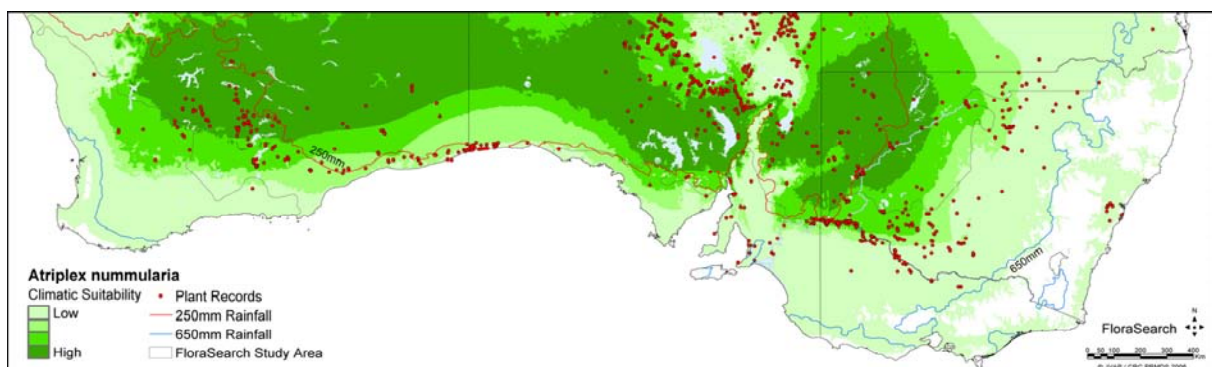
As previously mentioned, more orange wattle has been planted overseas than in Australia. In Australia, only 10 000 hectares are planted to assorted species of acacia with orange wattle the most common (Lefroy 2002b). Australian acacias and *Cassias* (now *Senna* species) have been grown in the West Asia–North African region (WANA) and orange wattle is the most important of these introduced acacias with approximately 200 000 hectares planted (Le Houerou 2000). Production of

3000–5000 kg DM/ha/yr and a crude protein content of 12–15% has been reported. Le Houerou (2000) advocates the selection of better forage types. (It was noted that orange wattle is very heterogenous and work is required to select a forage type and a wood type).

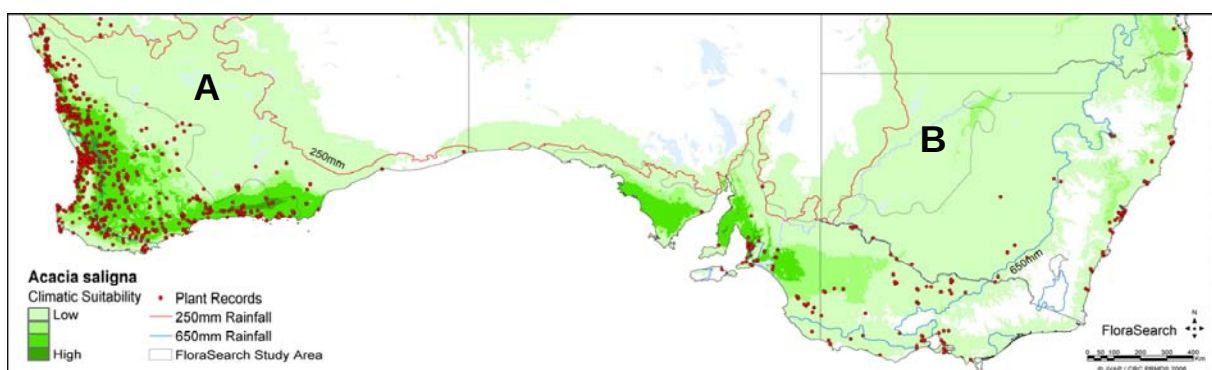
The genus *Acacia* is seen by Byrne and Broadhurst (2003) to be central in the development of new commercial species for the purpose of ameliorating salinity in low and medium rainfall areas. For WA, they listed three species of interest (*A. microbotrya*, *A. acuminata* and orange wattle *A. saligna*). They all have high morphological variation and each may consist of several taxa. However, they strongly emphasise the need to understand the taxonomic groups and genetic diversity as failure to do this will lead to a slow domestication process.

The domestication of orange wattle has centred on establishment and management techniques and its utilisation as feed for animals. Despite potential weediness problems associated with some acacias, the social, environmental and economic benefits likely will probably lead to their continued domestication (Midgley and Turnbull 2003). Following its recommendation as a focus species (Hobbs et al. in press), the FloraSearch project is currently testing orange wattle provenance variation in field trials in Western Australia.

Figure 2. Occurrence Of old man saltbush (*Atriplex nummularia*) and orange wattle (*Acacia saligna*) in southern Australia (source: Hobbs et al. in press)



The distribution and bioclimatic map of *Atriplex nummularia*



The distribution and bioclimatic map of *Acacia saligna*. Records from Western Australia show endemic range of the species (A). Records from other states show exotic distribution (B).

6.1.2 Chenopods (eg. saltbushes and bluebushes)

Six percent of Australia is occupied by shrub-steppe dominated by annuals and perennials of the family Chenopodiaceae. The most extensive areas occur in the predominant winter rainfall zone in South Australia, western New South Wales and south-eastern Western Australia (Leigh 1972). Chenopods are a highly specialised group of plants as described by Malcolm (1993) and in papers presented at a symposium on *Atriplex* (edited by Jones 1970). Some have evolved mechanisms to cope with waterlogged conditions such as aerenchyma and adventitious roots, but are not important in the context of this review. Other species have attributes that make them extremely drought hardy and only moderately palatable. These natural stands are used by, and highly regarded by, the pastoral industry for their stability in animal production when stocked at the correct grazing rates. If abused they can quickly deteriorate and the soils become vulnerable to erosion. Bladder saltbush, OMSB and several bluebush (*Maireana*) species are the dominant and important species in these landscapes. OMSB has exceptional resilience to grazing and it has been widely used to establish plantations outside its natural range. This is partly due to its strong woody frame that allows regrowth from many sites, a factor assisting its growth potential. However, OMSB relies on the absorption of salt to assist its growth and survival when water is limiting. These salts are accumulated in the leaves, the saltier the environment the more salt absorbed. As the leaves are ultimately eaten by stock, salt levels become an important consideration in livestock management. Management options are discussed in an Agfact *Getting the best from old man saltbush* (Honeysett et al. 2004).

Other woody species that may have potential are the goosefoots (*Chenopodium* spp.), especially nitre goosefoot (*Chenopodium nitrariaceum*) and golden goosefoot (*Chenopodium auricomum*). The natural distribution of both these species is in periodically flooded habitats, but it appears that this may only be a requirement for establishment as established plants grow well through otherwise dry times. If they can be successfully propagated the same way as OMSB then they should be considered further. Golden goosefoot is not as woody as OMSB and may require special management considerations for its persistence in a production system. It should also be determined whether they are salt accumulators like OMSB.

One of the first reviews of useful native Australian plants was the work of Maiden (1889) who described and listed many plants from across the continent. There are only few descriptions of forage shrubs, mainly of the chenopods mentioned in this review. He discusses the high regard that OMSB and bladder saltbush were held by the pastoral community and that much of the natural stands had disappeared due to overstocking. He specifically stated that both those plants were the ‘most fattening and wholesome of Australian pastoral saltbushes’.

It is interesting that the authoritative *Use of trees and shrubs in the dry country of Australia* (Hall et al. 1972) does not make any reference to the productive potential of plantation stands of forage shrubs. This omission reflects the ignorance that forage shrubs need to be integrated with other pasture for them to realise their potential. The authors do, however, describe in great detail attributes of many edible native species and their suitability as drought feed. One chapter is devoted to the detailed descriptions of the more useful and abundant chenopod species, discusses their drought tolerance, palatability, reaction to grazing as well as general management considerations. The main species named in that work are discussed in this section.

Approximately 140,000 to 240,000 hectares of OMSB have been established as plantations in Australia (URS Forestry in press). This contrasts with an earlier estimate of 50 000 hectares of saltbush, mostly OMSB (Lefroy 2002b). In Morocco, more than 50 000 hectares of the OMSB have been established (Le Houerou 2000), and extensive plantings have also been established in other Middle-Eastern countries. Le Houerou (2000) has quoted that well-maintained plantations of old man saltbush (OMSB) in South Africa and North Africa have lasted for 75 years and 40 years respectively.

The Australian plantings have generally been made for one of two purposes: on saline soils to reclaim them, or on non-saline soils to prevent dryland salinity and increase landscape resilience and productivity. When reviewing data it is important to know the purpose of the planting and the situation in which plants were grown.

6.1.2.1 Non-saline soils

In the Murray Mallee region of South Australia, OMSB is one of the two (the other being tagasaste) main forage species grown (Murray Mallee Local Action Planning Association 2003). However, many other chenopods have been mentioned as having potential on saline lands. In the Caliph area of South Australia, Malcolm (1993) noted that natural forage shrubs *Rhagodia* spp. and ruby saltbush (*Enchylaena tomentosa*) warranted further investigation. He suggested the best-bet species for South Australia are *Atriplex undulata*, *A. lentiformis*, *A. amnicola*, *A. cinerea* (Geraldton type), OMSB, *A. bunburyana* and *Maireana brevifolia*.

Murphy (1998) recommended OMSB for planting on non-saline sites in South Australia, but suggested two other species may also be considered, River Murray saltbush (*Atriplex rhagoidiodes*) and river saltbush (*A. amnicola*). Dooley (2001), in South Australia, mentions River Murray saltbush, a local species with potential to be productive and versatile, which has moderate tolerance to waterlogging. There is limited information on this species, but it is considered to have many characteristics similar to OMSB. In Victoria, there are 50 species of saltbush; the most utilised species is OMSB (Anonymous 2000).

In NSW, Milthorpe et al. (2001) listed eight commonly utilised species: bladder saltbush (*Atriplex vesicaria*), thorny saltbush (*Rhagodia spinescens*), cotton bush (*Maireana aphylla*), golden goosefoot (*Chenopodium auricomum*), nitre goosefoot (*Chenopodium nitrariaceum*), OMSB, black bluebush (*Maireana pyramidata*) and pearl bluebush (*Maireana sedifolia*). Patabendige (2001) identified plants (*Atriplex amnicola*, *A. undulata* and *A. cinerea*) with low growth habits with edible foliage that do not require mechanical harvesting as suitable species.

Dry matter yields of 1.5–2 t/ha/yr and water use efficiencies of approximately 5 kg DM/ha/yr/mm rainfall have been reported for OMSB (Wilson 1979; Milthorpe et al. 2000).

6.1.2.2 Saline soils

Old man saltbush has successfully been used to reclaim extensive areas of saline soils, with and without shallow water tables. Henschke (2001) also noted River Murray saltbush has potential on both saline and non-saline areas. Other saltland forage species suitable for South Australia include river saltbush (*Atriplex amnicola*) and this is quoted as the preferred species based on its salt and waterlogging tolerance (Henschke 2001). Lefroy (2002b) listed seven endemic saltbush species (*Atriplex amnicola*, *A. bunburyana*, *A. cineria*, OMSB, *A. paludosa*, *A. semibaccata* and *A. vesicaria*) along with three exotic species (*A. canescens*, *A. lentiformis* and *A. undulata*) that had been planted in Australia in the last ten years.

Dry matter production varies depending on the species and the environment in which the plants are growing. Nevertheless, some possess the ability to yield high biomass under ideal conditions. In WA, dry matter yields of 0.5–2 t/ha have been reported (Malcolm 1990). West and Schulz (1992), tested five species using saline irrigation water (16.6dS/m) and obtained the following yields (tDM/ha) 12 months after transplanting:

• <i>Atriplex amnicola</i>	8.1
• <i>Atriplex cinerea</i>	6.8
• <i>Atriplex nummularia</i>	7.7
• <i>Atriplex undulata</i>	5.8
• <i>Atriplex lentiformis</i>	2.7

They acknowledged that the yields were highly variable, but concluded that it indicates the potential that can be obtained with frequent irrigation on heavy clay soils. Morcombe et al. (1996) found in their trial that saltbush produced only 0.6 t/ha edible dry matter; however, this maintained the liveweight of 15 sheep/ha for 30 days.

6.1.3 Other native species

Many native trees have been used as drought fodder in the past. Feed for stock comes either from leaf fall as plants adjust to drought conditions by dropping some of their leaves, or from lopped branches of suitable trees. Inappropriate lopping of some species can cause death of the tree and in some circumstances the leaf can cause death of livestock, as in the case of feeding rosewood (*Alectryon oleifolius*) leaf to cattle in wet weather. Lopping is costly and time-consuming and today few people see this as a viable option. However it is important to review those species used to see if other harvest techniques make them a viable source of suitable fodder.

Chippendale (1963) stated that whitewood (*Atalaya hemiglauca*) would appear most valuable as a forage plant but as it tends to be grazed continuously, plants can be killed during drought. In the book, *Use of trees and shrubs in the dry country of Australia* (Hall et al. 1972) a chapter is devoted to important trees and shrubs not dealt with in the saltbush and other chenopod chapter. A total of 178 species are dealt with in this section (including 22 exotics and 34 acacias). Only 46 of the native species were regarded as having some value as drought forage, but only 17 were regarded highly. emubush (*Eremophila longifolia*), hopbush (*Dodonaea viscosa* subsp *angustissima*), wilga (*Geijera parviflora*), rosewood and belah (*Casuarina pauper*) have been analysed for nutrient status (Muir 1990) and results show that none of them are outstanding and of limited potential, especially when harvesting procedure is considered. Some also contain compounds that make them unpalatable to stock, further reducing their potential. Of the above, emubush and wilga have the greater potential. Additional moderately palatable tree species such as supplejack (*Ventilago viminalis*), wild orange (*Capparis mitchellii*) whitewood and kurrajong (*Brachychiton populneum*) have also been tested (Wilson and Harrington 1980) and found suitable.

A group of low shrubs and sub-shrubs from the hibiscus family (particularly *Sida* and *Abutilon* spp.) provide abundant feed to stock over the summer period, especially in response to rainfall events that are too small to initiate growth from annuals. These drought evaders have largely been overlooked in the past as potential forage species and several species warrant further evaluation, particularly, plains lantern-bush (*Abutilon halophilum*), ridge sida (*Sida cunninghamii*) and pin sida (*Sida fibulifera*). Their success will depend largely on the ease with which they propagate as it is most likely that they will need to be established by direct seeding techniques, due to the number of plants required to form a viable sward. Most of this group are free and large seeders.

There are a number of shrubby legumes that may have potential as forage plants, but many species from this group contain toxic alkaloids and have been reported as causing death in stock, the most notable being Darling pea (*Swainsona greyana*) and smooth Darling pea (*Swainsona galegifolia*). Animals grazing these plants become ‘pea struck’ and develop a craving for the plant and starve (Cunningham et al. 1981).

6.2 Exotic species

There are two main reasons why exotic forage plants may be seen as less favourable than natives, namely perceived weediness and lack of adaptation.

Due to the lack of forage/tree options in temperate Australia, Wheeler and Hill (1990) suggest that new sources of temperate shrub legume species could come from South America, the Mediterranean and high altitude areas of southern Africa; however, many exotic species carry the risk of becoming weeds. Exotics are not the only group of plants associated with weed risk. Australian natives such as orange wattle can become weeds even in Australia, particularly if they escape into national parks and reserves. Champion (1995) quoted the problem of orange wattle in Kuringai National Park, Sydney. Australian acacias are the most common exotic acacias introduced to southern Africa; however eight of the 19 species have become serious weeds (Fagg and Stewart 1994). Notably, the two most serious are orange wattle and *A. cyclops*. Lefroy (2002b) emphasises caution when considering the introduction of new exotic species because of the high woody weed risk. Most recently, Paynter et al. (2003) have reviewed the weed problem in Australia. Paynter et al. (2003) found the most serious weeds were exotic legumes that can form thickets and were often originally introduced to Australia for their perceived benefits such as shade, forage and garden ornamentals. The authors stress better predictive techniques need to be developed prior to further introductions into new environments because the behaviour of exotic species in new environments is very difficult to predict. Furthermore, exotic species are normally more vigorous than native species, therefore some people advocate (Paynter et al. 2003 quoted Hughes and Styles 1989) the use of native species over exotics even though the natives may be less productive. Paynter et al. (2003) state that, because some plants take a long time to disperse and colonise, plants currently being promoted could become future weeds. Historical records show that woody legumes are particularly risky with long time-lags between introduction and the development into a serious weed problem. They make several recommendations, including the re-assessment of the risks and benefits associated with the continued planting of tagasaste and leucaena.

Two of the most commercially acceptable forage shrub species in Australia are the exotics tagasaste and leucaena (Lefroy 2002b). Tagasaste was introduced into Australia and New Zealand in the 19th century (Francisco-Ortega et al. 1991). Most research relating to tagasaste has been carried out in Australia and New Zealand. One of the main reasons exotics may be preferred over local native forage species is the generally better productivity, digestibility and, in the case of tagasaste, less anti-nutritive compounds than many of the native species.

Tagasaste is considered a potential weed by association with the plant tribe *Genistae*, subtribe *Cytisus-Genista* (brooms and gorses). Most of this group of introductions are noxious weeds in Australia. Mesquite (*Prosopis* spp.) was introduced into Australia as a potential forage species about 70 years ago but is now regarded as a noxious weed in parts of Western Australia and NSW due to its thorny nature. Prickly acacia (*Acacia nilotica*) is another example of an introduced species that is regarded as a weed in Queensland. Le Houerou (2000) states that ecological and management constraints will increasingly influence the type of species (that is, exotic or native) selected.

6.3 Integration into existing farming systems

More information is needed on the water use and competition effects between forage shrubs and adjacent cropping plants in an alley farming system. Evidence to date from trials reported by Knight (1999), Lefroy (2000a) and Unkovich et al. (2003), indicates that alley farming systems in the low to medium rainfall zone may impose strong competition effects between forage shrubs and crops for water. Knight (1999) found no competition with crops in the first two seasons following establishment; however this was probably due to young forage belts in which the roots of shrubs had not reached far beyond the belt at that stage. Competition with crops had emerged by the third

season, oaten hay production was severely reduced 2 m out from the edge of the belts compared with further out in the alley (2100 kg/ha and < 3000 kg/ha at 5< respectively).

Lefroy (2002a) found in the first year of an alley farming trial utilising tagasaste, that the grain yield of lupins was 23% higher in alley crops compared to monoculture crops. However, by the second and third year, increasing levels of competition in alley treatments did result in yield decreases of 8% lower for oats and 32% lower for lupins respectively. When trees had regained a height of 5m after defoliation their lateral root influence extended to 8m; negative effects of competition on the crop outweighed the benefits of reduced drainage. These levels of productivity loss would be considered unacceptable, unless trees had a commercial product. Lefroy (2002a) concluded that growing trees in plantations may be a more appropriate strategy.

Lefroy (2002a) developed the drainage:yield ratio during this project. This will provide a useful tool for assessing the potential of incorporating perennial plants into cropping systems. It quantifies the trade-off between deep drainage and productivity in tree /crop mixtures. The ratio is calculated by measuring the distance over which trees effectively reduce yield to zero and the distance over which trees effectively reduce drainage to zero, the latter is divided by the former. When the ratio is greater than one, trees have a proportionally greater influence on drainage than yield, therefore trees would be of greatest benefit mixed in with crops in an alley system rather than as monocultures. But, when the ratio is less than one, it is best to separate trees from crops by growing them in plantations. In the trial (Lefroy 2002a) the drainage:yield ratio was 0.6, and a plantation would have been best. Unkovich et al. (2003) found no evidence of crop yield increases due to tree and shrub belts at any of the three sites they studied (Pallamana, SA; Walpeup, Vic. and Bridgewater, Vic.). In fact, the no-yield zone was greatest at Walpeup, the driest site (8.8 m), then Pallamana (7 m) and Bridgewater (6.4 m). Unkovich et al. (2003) calculated the drainage:yield ratios for the three sites; they are as follows: Pallamana = 1.00, Walpeup = 0.79 and Bridgewater = 0.78. On this basis alone the authors concluded that alley farming at Walpeup and Bridgewater was not suitable and Pallamana was marginal. The competition effects between seven-year old tree and shrub species—swamp yate (*Eucalyptus occidentalis*), orange wattle and *Casuarina obesa*—and adjacent pasture was examined by Woodall and Bruce (2002). All three species reduced pasture yield under trees and up to 2m away. However, orange wattle and *C. obesa* had the least impact and reduced yield of pasture by 14% and 22% respectively, compared to 40% reduction caused by swamp yate. The reasons for the differences between species are unclear.

Integration of forage crops into cropping systems does not necessarily imply an alley farming system but could also mean a separate area set aside for forage shrubs in a plantation. Le Houerou (2000) suggests planting a corner of each paddock so it can be easily fenced and managed. In addition, forage shrub areas can be used to spell pasture paddocks (Atiq-ur-Rehman 2002), particularly at the break of season to give new or regenerating pastures a chance to establish (Milthorpe et al. 2001).

However, the question still remains, ‘Do you sow a single species or grow a mixed stand consisting of several species?’ There are pros and cons for both approaches. Lefroy (1994) showed a mixture of three forage shrubs (tagasaste, orange wattle and *Rhagodia preissii*) yielded significantly more edible dry matter than the any of the species in monoculture. In polyculture, *Rhagodia preissi* benefited from the presence of the other two species (orange wattle and tagasaste) with a 64% increase in productivity. This may be due to orange wattle and tagasaste being nitrogen fixers and/or that they provided physical protection to *R. preissii*. Lefroy (1994) acknowledged that the management of mixed stands of forage shrubs would be difficult due to differences in palatability and that mixtures will only be of value if they persist over time and are relatively easy to manage. Knight et al. (1998) also stressed mixed species can present problems due to differences in palatability. More palatable species will be eaten out first. However, the authors recommend a mixture of 3–4 species to take into account wide variability in soil types within a paddock; this will ensure at least one of the species will persist in part or the whole paddock. Stirzaker and Lefroy (1997) quoted an example of tagasaste being grazed out selectively from an orange wattle+tagasaste alley belt. Le Houerou (2000) maintained that if forage production is the main purpose it is best to use single species stands, mainly

because different species have different requirements for maximum production (eg. the rhythm of utilisation is often different between species). Palatability and preference are also variable between species, therefore palatable species mixed in with less palatable species will eventually lead to the disappearance of the more palatable species, particularly if the same grazing regime is used repeatedly. Based on Le Houerou's experience, he advocates the use of several species but planting each species in a separate paddock.

6.4 Animal/plant interaction—Rumen microbiology

Some livestock and wildlife seem able to cope with consuming forages with high tannin content or other anti-nutritive compounds in plants. The mechanisms by which they achieve this tolerance are via tannin binding salivary proteins, tannin-resistant or tannin-degrading micro-organisms in the digestive tract (rumen and intestines) and by other potential adaptations in the lower intestinal tract (Brooker et al. 2000). Diverse populations of tannin-tolerant bacteria have been isolated from feral livestock and wildlife (Brooker 2000). Inoculation of less tolerant livestock with the rumen fluid from tolerant livestock is one approach to improve forage utilisation. Brooker (2000) emphasises that the manipulation of rumen microflora appears to be a promising approach if exotic organisms can be isolated and can persist in the rumen.

During a visit to South Africa, Lefroy (1995) noted that in sheep, the rumen bacteria from dorpers had been used to inoculate merinos; subsequently the merinos were better able to utilise saltbush. He concluded this offers the possibility of utilising hardy plants such as saltbush in Australia. Atiq-ur-Rehman (2002) made mention of the higher intake of saltbush by animals from countries where they survive mostly on poor quality diets (eg. Libya) compared to those animals mostly raised on good quality diets (eg. Australia). He concluded animals reared on poor quality diets may be better equipped to utilise poor quality pastures.

Odenyo et al. (1999) tested the assumption that indigenous livestock are better adapted to consuming high tannin feeds. The rumen fluids from indigenous African ruminants were tested for their capability to ferment the leaves of *Acacia angustissima*, *Calliandra calothyrsus*, *Leucaena diversifolia*, *L. leucocephala*, *L. pallida* and *Tephrosia bracteolata*. The main purpose of the trial was to determine the presence of tannin-degrading microbes. There was a significant rumen fluid by forage type interaction. Addition of polyethylene glycol (PEG) improved the fermentation of various rumen fluid sources. Results also showed that tannin and phenolic monomers were successfully hydrolysed by all rumen fluid sources. The authors concluded that the rumen fluid from goat, gazelle, Gunther's dik-dik and impala were capable of fermenting the tannin-rich forage; therefore they may be a source of tannin tolerant or degrading micro-organisms. Jones et al. (2001) also hypothesised that game species (eg. giraffe) which generally browse on high tannin-containing forages may have condensed tannin (CT) tolerant rumen microflora. The digestive ability of *in vitro* rumen fluid from wild game animals was compared to that of sheep using forage species containing condensed tannins. Leaves from six shrub legume species (*Leucaena leucocephala*, *L. pallida*, *L. trichandra*, *Calliandra calathyrus*, *Gliricidia sepium* and *Acacia boliviana*) were used to assess *in vitro* digestibility (IVDMD), nitrogen content (IVND) and the effects of CT with and without polyethylene glycol (PEG). In addition the rumen fluid from wild game animals (giraffe, greater kudu, eland, duiker, impala, nyala, goat and gnu) was compared to that of sheep for the ability to cope with CTs. In contrast to the results of Odenyo et al. (1999), no significant animal by feed interaction was found. All animal species responded to the PEG treatment for IVND, indicating no special ability to metabolise or block the negative effects of CT. The main conclusion from this study was that rumen microbial populations from wild game animals (browsers) are no better at coping with tannin-rich forages than the grazers (sheep). Furthermore, the authors suggested that tolerance of high CTs may be more dependant on proline-rich saliva than on tolerance of rumen bacteria to CTs. They also suggested it may be better to exploit the differences in CT levels in different species and between accessions/provenances of plants than to seek tannin-degrading bacteria for the inoculation of domestic livestock.

Brooker (2000) stated that research in Adelaide showed that feral goats could browse mulga (containing tannins) without any adverse effects. Furthermore, the work also showed that rumen fluid transferred from goats to sheep allowed the sheep to successfully digest acacia without any ill effects. Researchers are beginning to identify the micro-organisms responsible for tannin-resistance and tannin-degradation (Tjakradidjaja et al. 2000).

There is still much to understand in the research field of tannin and other anti-nutritive compounds and how they interact with animal production. McSweeney et al. (2002) state that research on anti-nutritive compounds in forage/trees has been fragmented, partly because there are a large number of secondary compounds involved and methods of identification have not been standardised. Therefore, to improve the utilisation of forage trees and shrubs will require a more thorough understanding of secondary compounds. McSweeney et al. (2002) support the further search and understanding of micro-organisms which may be used to improve the utilisation of forages. They foresee that the manipulation of rumen microbial ecosystems offers opportunities to alleviate some of the problems associated with anti-nutritive compounds in forage shrub/trees. Tannin-tolerant micro-organisms are more likely to be found in regions of the world where tannin-rich plants form a natural component of the ruminant diet (McSweeney et al. 2000). Krebs et al. (2003) also noted in the literature there was a lack of uniformity in how information on tannins is presented. They state there is a need for standardising the analyses of phenolics.

6.5 Concluding remarks

Australia has three major groups of native plants that contain potential forage shrub species, namely acacia, saltbush and hibiscus. There are many species of acacia and saltbush that warrant further investigation for their forage value, yet very little systematic testing has been done, particularly those species from SE Australia. In the case of the saltbushes it will be very important to evaluate them for nutritive value and persistence while growing on non-saline soils, because on highly saline soils their nutritive value is limited by excessive salt content. Evaluation of forage shrub species should be made in the context of not having to provide the sole source of feed, which was often the situation in the past. Although acacias and saltbushes offer great potential, other lesser-known genera such as *Sida* spp. and *Abutilon* spp. should not be overlooked. The introduction of new exotic forage species needs to be very carefully considered due to perceived high risk of weediness. This is particularly the situation for spiny leguminous shrubs.

The shortcomings of forage shrubs in relation to anti-nutritive factors need to be tackled on many fronts, such as the study of rumen microbiology, the selection of plants with low concentrations of ANFs and the strategy of mixing high ANF forages with low ANF feed sources. Rumen microbiology offers the opportunity to further understand the effect of ANFs on animal productivity. It may also provide part of the solution via the identification of livestock with ANF tolerant micro-organisms, which may be used to inoculate non-tolerant animal species, enabling them to better utilise the forage shrub.

There are other questions that need to be addressed when evaluating potential species, especially plant structure. Edible tree species, which quickly grow beyond bite-height, supply only limited feed as leaf fall and trees need to be lopped to make forage available. This latter option is costly and probably not cost-effective under current economic conditions.

How forage shrubs are integrated into farming systems will depend on their intended role (forage and/or environmental services). If recharge control is sought, careful thought has to be given to planting layout such as alley or block plantings. Competition between shrubs and crops for water can lead to reduced crop yields adjacent to shrub belts in low to medium rainfall farming regions. It will be vital to understand competitive interactions between the different species and combinations of shrubs and crops.

Key points

Forage shrubs:

- offer functional increase in landscape biodiversity
- offer increased environmental stability through stock protection and reduction in soil erosion
- offer increased soil microbial activity
- offer suitable native species from the groups Acacia, Chenopods and Malvaceae.

Land managers:

- need to integrate them into farming systems
- need to give additional management for plantation and stock
- need to make the distinction between saline and non-saline production
- need to consider the impact on animal stomach micro-organisms caused by anti-nutritive factors (ANFs)
- need to determine careful placement/layout in the landscape.

7. Knowledge gaps

Our review identified several knowledge gaps regarding the use of forage shrubs and trees. These are:

- understanding of animal production requirements
- development of management protocols for the integration of forage shrubs into existing farming systems and greater understanding of water use and competition effects
- new species evaluation to identify more adaptive, productive and nutritious species
- a greater understanding of the effect of anti-nutritive factors in forages
- economic analyses of whole-farm systems
- extension of existing knowledge.

Dealing with each point:

- *Understanding of animal production requirements*

Feed requirements for different species of animals (eg. cattle versus sheep), for the full year (including lactating stock), need to be well understood prior to planning the extent of forage shrub plantings. This has to be integrated with seasonal rainfall patterns.

- *Development of management protocols for the integration into existing farming systems and greater understanding of water use and competition effects*

More research is required to understand competition and complementary effects in plantations and alley systems of forage shrubs. Atta-Krah (1993) advocates the need to understand the compatibility of forage trees and shrubs with pastures and crops, without reducing yields. The drainage:yield ratio developed by Lefroy (2002a) will provide a useful tool for assessing the potential of incorporating perennial plants into cropping systems. However, more data is needed about different forage species in different regions and soil types of Australia. The studies in natural systems should not be overlooked for they can provide guidance as to which species may be compatible in an integrated cropping system. Forage shrubs have the ability to extend feed availability and quality across seasonal feed gaps. This will increase total (\$) output by allowing better marketing of product and reduced risk in production.

- *New species evaluation to identify more adaptive, productive and nutritious species*

Wildin (1992) proposed the need to identify regions of Australia, based on environmental factors, where forage trees could have an important role in sustainable agriculture and livestock production. Regions include semi-arid tropics, subtropics and temperate regions with less than 450 mm annual rainfall. Furthermore, provenance trials of both native and exotics need to be established. These also have to identify those species with the potential to become weeds and develop control methods. Malcolm (1993) mentioned the need for further species evaluation in South Australia and the search for more digestible acacia lines. Le Houerou (2000) also advocates the search for more digestible forage acacias, particularly orange wattle. He also stresses the importance of knowing the productivity of different species in terms of the number and height of defoliation, length of recovery period and life span of leaves and twigs. Dynes and Schlink (2002) also suggested more research on Australian acacias. They found it ironic that Australia has a significant number of the world's Acacia species, yet very little systematic research has been done on them with regard to their potential for animal nutrition. Furthermore, they state that acacia utilisation in Australian farming systems could be increased through the selection of species for livestock feed (particularly for seasonal feed gaps); however, accessibility of forage and the negative influence of secondary compounds need to be addressed.

Lefroy (2002b) asserted that new forage shrub and tree species, particularly indigenous species, have to prove their worth in terms of quality and quantity before any consideration can be given to their commercial value. He found very few examples of studies that compared new alternative shrub and tree species with conventional feed sources in relation to their commercial prospects. To address this he recommended further research into tagasaste and leucaena in Australia because these species have already demonstrated a reasonable level of commercial acceptance as well as high nutritive value. Lefroy stated that preliminary data from candidate species should meet certain basic requirements (that is, 1 tDM/ha and 55% digestibility) before further investment is made in plant selection, breeding and grazing experiments. These recommendations would only cover forage shrub and tree options for the tropics/sub tropics and the south-western regions of Australia. Therefore, indigenous forage species need to be sought specifically for south-eastern Australia. The study by Lefroy (1994) evaluated both exotic and indigenous forage species on the acidic soils of Western Australia, making the relevance of that study to south-eastern Australia limited due to the dominance of alkaline soils and heavy textured soils.

Indigenous species of south-eastern Australia have not been systematically evaluated for their forage potential. Any evaluation should be made in the context of providing a complementary feed source rather than meeting sole nutritional requirements of livestock. Where possible the search for new germplasm should include taxonomic studies (Byrne and Broadhurst 2003, Midgley and Turnbull 2003) to add to our understanding of the levels of diversity. Dynes and Schlink (2002) highlight that toxins such as oxalate, flouroacetate, and hydrogen cyanide should be screened early in a selection program and only those species or provenances with low levels considered for further development. In the report by Kingwell et al. (2003), it was noted that certain regions of Australia had very few profitable, deep-rooted perennial species available.

- *A greater understanding of the effect of anti-nutritive factors in forages*

A better understanding of the interaction of anti-nutritive factors with rumen microbiology is warranted (Wildin 1992, Brooker 2000, LeHouerou 2000, McSweeney et al. 2002). This will be a slow process. McSweeney et al. (2002) noted that the technology that led to the use of specialised mimosine-degrading rumen bacteria to prevent leucaena toxicity took between 5–10 years to develop following the initial discovery of microbial detoxification of the plant. Brooker (2000) describes the research priorities for tannins in terms of animal nutrition, tannin chemistry and digestive microbiology.

- *Economic analyses of whole-farm systems*

Economic analyses need to be made in the context of the whole-farm systems. Milthorpe et al. (2001) recommend further studies be undertaken to quantify the benefits of forage shrubs for a range of management options. The environmental and ‘public benefit’ value need to be determined and accounted for. This may require incentive schemes to be developed to assist farmers in best realising ‘public benefits’.

- *Extension of existing knowledge*

New farming innovations of any kind need to demonstrate profitability and environmental advantages, otherwise extension activities will be largely ineffective. Wildin (1992) recommended that extension (of information) about forage shrubs and trees use printed and computer packages, including economic analyses. A strong emphasis needs to be placed on forage shrubs being a complementary feed source, not the sole feed source.

8 Discussion of recommendations made in earlier reports

This section deals with a request in the terms of reference for this project to address the concerns about forage shrubs that were raised in the review conducted by Lefroy (2002b). In that report he made several recommendations for further research and raised matters relating to the potential use of indigenous forage shrubs in Australia. Summarised these are:

- no indigenous forage shrub to date has reached the commercial acceptance level of tagasaste and leucaena
- further research should be invested in tagasaste and leucaena because they have proven their worth
- new exotic forage shrub species should not be introduced due to their high weed risk potential
- before extensive investment is made into indigenous species there must be proof that they meet the basic criteria of producing 1 tonne edible DM/ha and have at least 55% digestibility.

Dealing with each point:

- *No indigenous forage shrub to date has reached the commercial acceptance level of tagasaste and leucaena.*

We believe the failure of many indigenous species has been due to unrealistic expectations, through trying to fit indigenous forage shrubs into old paradigms. In other words, expectation was put on the forage shrubs to meet most if not all of the nutritive requirements of livestock. As outlined in section 4.1 and 4.2, forage shrubs should be considered as a complementary feed source and not as a sole feed source. Very few, if any, conventional pasture species grown on their own can offer a complete balanced diet to livestock. Even lucerne when planted and managed as a pure stand can present management problems and death of livestock through the disease ‘redwater’. Hence, it is unreasonable to expect forage shrubs to provide a balance diet alone. In the treatment of saltbushes, almost all references are from studies where plants are grown on saline soils or in areas where there is a shallow (and mostly saline) watertable. In these situations saltbushes offer little potential as a production source of forage due to high leaf salt content and should be only considered for their environmental benefits in reclaiming these lands. There are however, vast areas of land in south-eastern Australia that are non-saline, but susceptible to the threat of dryland salinity. Saltbushes have potential to address this threat and at the same time provide an economic benefit.

- *Further research should be invested in tagasaste and leucaena because they have proven their worth.*

The success of tagasaste and leucaena did not happen overnight. It has been a long journey of research and development for both species in Australia. Even conventional pasture species (eg. subterranean clover) have gone through a similar long history of research and development in this country to reach the level of prominence they currently have. Many obstacles had to be overcome, most notably the selection of low oestrogen subterranean clover cultivars (high oestrogenic cultivars caused sheep infertility). Further research on tagasaste will mostly benefit Western Australia and some near-coastal areas of southern Australia, because much of south-eastern Australia is unsuitable for tagasaste (Milthorpe and Dann 1991) due to soil (texture and high pH) and climatic constraints (frosts). Further research on leucaena would only be relevant to the tropics and sub-tropics of Australia, outside the area of this study.

- *New exotic forage shrub species should not be introduced due to their high weed risk potential.* We agree; indigenous forage species pose lower weed risk and in some situations are better adapted than exotic species (see section 6.1).

- *Before extensive investment is made into indigenous species there must be proof that they meet the basic criteria of producing 1 tonne edible DM/ha and have at least 55% digestibility.*

The basic criteria used by Lefroy (2002b) have shifted from his earlier citing (Lefroy 1994). He initially stated new forage shrubs need to meet the basic requirement of producing 1 tonne edible dry matter/ha/100 mm rainfall. Later, Lefroy (2002b) refers to 1 tonne edible dry matter/ha of combined shrub and inter-row pasture, but no rainfall caveat is mentioned.

The latter statement is vastly different from the former. Our findings suggest that the first mentioned requirement is too optimistic for south-eastern Australia, as yield estimates would be about twice that obtained from recent studies of woody plants. Similarly, the latter condition would be too low for those areas receiving more than 300 mm annual average rainfall (AAR).

It is difficult to comment on the digestibility value as this is affected by many factors. It appears from Lefroy's reports that there is a presumption that these feeds will be managed largely as a mono-specific source of feed. That is not an option that we would endorse.

A point not raised in either review by Lefroy (1994, 2002b) but an important consideration for forage shrubs is that the three species he nominated as having the greatest potential all possess common attributes that assist their chances of success in grazing systems. One attribute is having a large woody frame that protects the plant's structure as well as giving it many new regrowth points following grazing. Another is their palatability rating, which is only moderate; this is a desirable attribute to prevent severe defoliation early in the grazing period.

Key points

Land managers:

- need to consider plant production potential of forage shrubs
- need to consider weed potential of new exotic species
- need to consider the importance of plant conformation, for example a large woody frame to protect the plant and supply a large number of new growing points.

9. Conclusions

While it is acknowledged that annuals have the potential to provide greatest dry matter production, it is stressed that this is not the most important factor in driving agricultural production especially in areas with a highly variable and/or seasonal rainfall pattern. Similarly, monocultures are not the most desirable systems to optimise production and there is a need to consider total feed supply and quality for the whole year and not rely on laboratory tests in determining suitability. The concept of using forage shrubs as a drought feed has largely failed due to the inappropriate diet they supply, and difficulties in managing for this. Rather, a mixed diet of annuals and shrubs is recommended for use as standard seasonal practice, and that this combination is used for animal production rather than animal maintenance.

The prospects to introduce new forage shrub species may be limited by a number of factors such as the presence of anti-nutritive factors and toxins as well as inherent plant attributes. Impediments to establishment may eliminate otherwise valuable species. It appears that a woody superstructure and moderate palatability are important considerations in determining a plant's ability to persist in agricultural environments, even under good management. These factors need to be carefully considered in future selection work and may be the main reason why other potentially productive perennials have failed past evaluations.

We believe there are very strong prospects for the use of forage shrubs and trees in the low rainfall mixed-farming systems compared to other alternatives (eg. biomass production or speciality products). Established markets and industry infrastructure already exist for the end products (e.g. lamb and wool) making widespread adoption of forage shrubs into existing mixed-farming enterprises much easier. This is in contrast to other prospective new farming industries that may take considerable time to establish as market outlets and a stable industry infrastructure. Also new enterprises need an industry champion to promote their cause.

We recognise that there are both positive and negative attributes associated with integrating forage shrubs into farming systems, but believe that with good management of both plants and animals, the positive attributes outweigh the negative ones. The end results are increased production and profit to the landholder as well as greater environmental benefits to the landscape. Further research to determine optimum species and management is needed.

10. Recommendations

Further work on assessing forage shrubs should include:

- compiling lists of potential species for each of the major landscapes
- collecting comparative data on morphology, phenology and production for potential species
- using this data, select suitable species for use in integrated mixed-farming systems
- quantifying both the economic and environmental benefits of integrating forage shrubs into mixed-farming systems
- demonstrating, at farm level, that integrated mixed-farming systems are beneficial
- developing management protocols for successful species
- publishing available knowledge on suitable species.

We also request that governments consider the public environmental benefits afforded by large scale adoption of fodder shrubs in an integrated production system and assist by offering incentives to land users on behalf of the public.

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Appendix – list of forage species referred to in report

Scientific name	Common name (or notes from report)
Southern Australia	
<i>Acacia acuminata</i>	jam wattle
<i>Acacia aneura</i>	mulga
<i>Acacia argyrophylla</i>	silver mulga
<i>Acacia cambagei</i> , <i>A. georginae</i>	have been linked to poisoning of livestock; however this is uncommon and most likely to occur if abnormally high amounts of foliage are eaten.
<i>Acacia canescens</i> ,* <i>A. lentiformis</i> *, <i>A. undulate</i> *	three exotic species
<i>Acacia decurrens</i>	black wattle
<i>Acacia excelsa</i>	ironwood
<i>Acacia microbotrya</i>	
<i>Acacia murrayana</i>	sandplain wattle (palatable but possible poisoning of stock if abnormally high amounts eaten)
<i>Acacia salicina</i>	cooba, willow wattle (palatable but possible poisoning of stock if abnormally high amounts eaten)
<i>Acacia saligna</i>	orange wattle
<i>Alectryon oleifolius</i>	rosewood (feeding leaf to cattle in wet weather can cause death of livestock)
<i>Atalaya hemiglauca</i>	whitewood (most valuable as a forage plant but as it tends to be grazed continuously, plants can be killed during drought)
<i>Atriplex amnicola</i>	river saltbush (one of the best-bet species for South Australia, according to Malcolm 1993)
<i>Atriplex cinerea</i>	one of the best-bet species for South Australia, according to Malcolm (1993)
<i>Atriplex nummularia</i>	old man saltbush
<i>Atriplex rhagoidiodes</i>	River Murray saltbush
<i>Atriplex stipitata</i>	bitter saltbush
<i>Atriplex vesicaria</i>	bladder saltbush
<i>Atriplex bunburyana</i> , <i>A. paludosa</i> , <i>A. semibaccata</i> , <i>Atriplex undulata</i> , <i>A. lentiformis</i> (Geraldton type)	other endemic saltbush species (some are potential best-bet species for South Australia, according to Malcolm 1993)
<i>Brachychiton populneum</i>	kurrajong
<i>Capparis mitchellii</i>	wild orange
<i>Cassias</i> (now <i>Senna</i> species)	
<i>Casuarina cunninghamiana</i>	river oak
<i>Casuarina pauper</i>	belah
<i>Chamaecytisus palmensis</i> *	tagasaste
<i>Chenopodium auricomum</i>	golden goosefoot
<i>Chenopodium nitrariaceum</i>	nitre goosefoot
<i>Dodonaea viscosa</i> subsp <i>angustissima</i>	hopbush
<i>Enchylaena tomentosa</i>	ruby saltbush
<i>Eremophila forrestii</i>	Wilcox bush, grey poverty bush

<i>Eremophila longifolia</i>	emubush
<i>Eremophila maitlandii</i>	tall, or Shark Bay poverty bush
<i>Geijera parviflora</i>	wilga
<i>Leucaena</i> sp.*	leucaena
<i>Maireana aphylla</i>	cotton bush
<i>Maireana brevifolia</i>	small-leaf bluebush (one of the best-bet species for South Australia, according to Malcolm 1993)
<i>Maireana pyramidata</i>	black bluebush
<i>Maireana sedifolia</i>	pearl bluebush
<i>Rhagodia parabolica</i>	mealy saltbush
<i>Rhagodia preissii</i>	
<i>Rhagodia spinescens</i>	thorny saltbush
<i>Rhagodia ulicina</i>	spiny goosefoot
<i>Ventilago viminalis</i>	supplejack
northern Australia	
<i>Acacia shirleyi</i> , <i>A. cowleana</i> and <i>A. hylonoma</i>	species with relatively high digestibility and protein content based on lab analyses by Vercoe (1988)

Common names are as used in this report, supplemented from Milthorpe and Wynne (2004).

* exotic species

Milthorpe and Wynne (2004) includes a list of known forage species for central west New South Wales. A list of potential forage species is given in Bennell et al. (in press).