An economic review of key perennial forage systems on the South Coast of Western Australia

Prepared for:

SOUTHCOAST NATURAL RESOURCE MANAGEMENT INC.

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International applied research specializing in agricultural, environmental and fisheries economics

Australian Government

This project is supported by South Coast NRM through funding from the Australian government.

February 2017

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Acknowledgements

The author would like to thank the Australian Government for funding the project, and the following people who were available to discuss various issues in relation to the compilation of this report:

- Julia Fry, Consultant,
- Ronald Master, Department of Agriculture and Food Western Australia,
- Gonzalo Mata, CSIRO Agriculture and Food,
- Charlotte Powis, South Coast NRM Inc.,
- Paul Sanford, Department of Agriculture and Food Western Australia, and
- Ian Walsh, landholder in Cranbrook.

Executive Summary

South Coast Natural Resource Management Inc is conducting a project funded by the Australian Government's Carbon Farming Futures Program which is designed to provide farmers and land managers along the South Coast with methods of reducing methane emissions through demonstrating a variety of perennial grazing systems compared with annual unimproved pastures. Advanced Choice Economics Pty Ltd has been contracted by South Coast NRM to conduct an economic review of four trialled farming systems compared with a 'business as usual' system of annual unimproved pasture as well as a 'do nothing' scenario of unimproved marginal farmland. The main findings of the review for each of these systems are provided below.

1. 'Business as usual' – Annual unimproved pasture

Native unimproved pastures are still a significant component of the pasture resource in the South Coast of Western Australia, even though large areas have been replaced or modified with improved grasses, legumes and/or forage crops. Costs specific to pasture implementation and maintenance for volunteer pasture are generally negligible, especially in the lower rainfall zones. As these costs are low, it is a low risk land management option. The difference in production between improved species and volunteer species gets smaller as sites become more severely affected by salinity and/or waterlogging. Gross margins of annual volunteer pastures are heavily influenced by output prices, the control of feed demand and net pasture production. Annual unimproved pasture is generally a viable option, even if it is not the most profitable one. The exception is in low rainfall zones when output prices and stocking rates are low. The profitability of annual unimproved pasture can be very rewarding in very high rainfall zones when output prices and stocking rates are high.

2. Kikuyu perennial grass pastures

Perennial kikuyu pastures have two key benefits: (1) they have a deep root system which enables them to use water and nutrients from deeper soil layers than annual plants, and (2) they can extend the growing season at both ends when conditions are favourable. Kikuyu is very well suited to the conditions of the South Coast of Western Australia and has proven to be one of the most widely adopted perennials on the South Coast of WA. Economic review of perennial pastures indicates that the gross margin of kikuyu pasture is heavily influenced by the rainfall zone and area of perennial pasture in the system. Kikuyu has significant impacts on stocking rate and supplementary feeding required. Profitability of kikuyu paddocks starts at $65/ha/year in the medium rainfall zones, and approximately doubles for the high rainfall zone ($125/ha/year) and the very high rainfall zone ($240/ha/year). This is approximately $10 and $20/ha/year more than annual volunteer pastures in the high and very high rainfall zones, respectively, and is similar to improved pastures in the medium rainfall zone.

3. Saltbush-based forage systems with annual pasture understory

Saltbush and annual understory is now the option most recommended for saline sites with low to medium rainfall. The most common saltbush species planted on salt-affected land on the South Coast include Old Man saltbush and River saltbush. The climatic requirements for this system depend on the suitable rainfall range for saltbush stands; which is approximately 250 – 450mm. There are significant production and environmental benefits from revegetating saline land. The economic benefits to the livestock enterprise is additional green feed grazing opportunities for approximately 120days/year with a stocking rate of approximately 20DSE/ha. Establishment costs are approximately $400/ha and maintenance costs are approximately $60/ha. Over a 10 year period, the system breaks-even in about the fourth year after establishment, and the indicative annual equivalent profit is approximately $28/ha/year. Saltbush and annual understory has the potential to be unprofitable with low stocking rates and low output prices.

4. Combination of perennial grass and saltbush

Saltbush-based forage systems with a perennial pasture understory have similar production advantages and disadvantages, environmental advantages and risks compared with an annual pasture understory. However, a perennial pasture understory is generally expected to store more soil carbon, have greater management requirements and can have greater nutritive benefits than an annual pasture understory. The economic benefits to the livestock enterprise of saltbush forage systems with perennial understory is additional green feed grazing opportunities for 15DSE/ha for approximately 120days/year. Establishment costs are approximately $380/ha and maintenance costs are approximately $35/ha, with breakeven expected in year 5. Over a 10 year period, the indicative annual equivalent profit is approximately $21/ha/year, which is sensitive to output prices and stocking rate. A saltbush-based forage system with a perennial pasture understory is expected to have less opportunity for high profits but less risk of being unprofitable, compared with a saltbush and annual understory.

5. Mixed shrub systems with saltbush

Mixed shrub systems may include blue bush, quailbrush, tar brush, nitre bush and several species of saltbush. Mixed shrub systems are currently in trial phase along the South Coast of Western Australia, with no full-scale adoption known to the author. The adoption of perennial forage shrubs, both indigenous and introduced species, in saline agricultural landscapes may increase the area of productive land, improve nutrient cycling and carbon sequestration in poor soils, and provide a source of nutrient to livestock at key times of the year to overcome feed gaps. The production advantages and disadvantages, environmental benefits and risks of this system are expected to be similar to those for saltbush-based forage system with pasture understory. Anecdotal evidence suggests that current mixed shrub species as yet do not achieve the economic benefits currently achieved by saltbush-only forages, although this has not been proven.

6. 'Do Nothing' – unimproved marginal farmland

Where soil is marginal due to high-levels of salinity or waterlogging, the most economic use for the land may be to do nothing; except perhaps fence it to prevent grazing. This has the advantage of being relatively low-cost and low-risk compared with other more pro-active options, and if sheep are excluded from the site, it includes benefits of improvements in groundcover and land rehabilitation. Economic analysis suggests that a 'do nothing' scenario may be the best economic alternative if wheat yields are lower than approximately 0.8 – 1t/ha, stocking rates are less than approximately 1.2 – 2.7DSE/ha or if intensive stocking rates for part of the year on saltbush with perennial pasture is less than approximately 12 DSE/ha, depending on the rainfall zone and market prices.

Contents

1. Introduction

South Coast Natural Resource Management Inc. (South Coast NRM) secured Action on the Ground funding for the project “Capitalising on perennial forages suited to the Western Australian South Coast to reduce methane emissions intensity”. Action on the Ground is a component of the Australian Government’s Carbon Farming Futures Program that assists farmers and land managers to undertake on-farm trials of abatement technologies, practices and management strategies to measure and demonstrate how they can reduce agricultural greenhouse gas emissions or increase the sequestration of carbon in soil while maintaining or improving farm productivity. South Coast NRM’S project aims to provide farmers with methods of reducing methane emissions through demonstrating a variety of perennial grazing systems compared to an annual “business as usual” system found on the South Coast. Information generated will enable farmers to make informed management decisions that will improve productivity, increase efficiency and bottom line profit. The project measures soil carbon under different perennial and annual grazing systems.

As part of this project, South Coast NRM contracted the author to conduct an economic review of each of their demonstration sites to assess each of the grazing systems in terms of productivity and production costs for implementing and maintaining these systems, and to summarise the benefits to the farming enterprise. This review is intended to add value to the scientific review of the methane emissions and soil carbon data and also highlight the costs, benefits and outcomes in a format that enables production decisions to be easily made by farmers.

The economic review includes each of the following land management systems conducted at the demonstration sites:

a. ‘Business as usual’ - Annual unimproved pasture
b. Kikuyu perennial grass pasture
c. Saltbush-based forage system with annual pasture understory
d. Combination of perennial grass and saltbush
e. Mixed shrub systems with saltbush
f. ‘Do nothing’ - Unimproved marginal farmland

The South Coast region is described in Section 2. The methodology for conducting the review is provided in Section 3, and the economic review itself is contained in Section 4.

2. The South Coast Region

2.1 Climate

The climate along the South Coast of Western Australia (Figure 1) is Mediterranean with cool wet winters and dryer hot summers, although there is a reasonable amount of summer rainfall, increasing near the coast. The western part of the zone near Albany experiences average annual rainfall of between 450 – 900mm. The eastern part of the zone near Esperance experiences average annual rainfall of between 400 – 650mm. Rainfall declines sharply across the south coast towards inland areas.

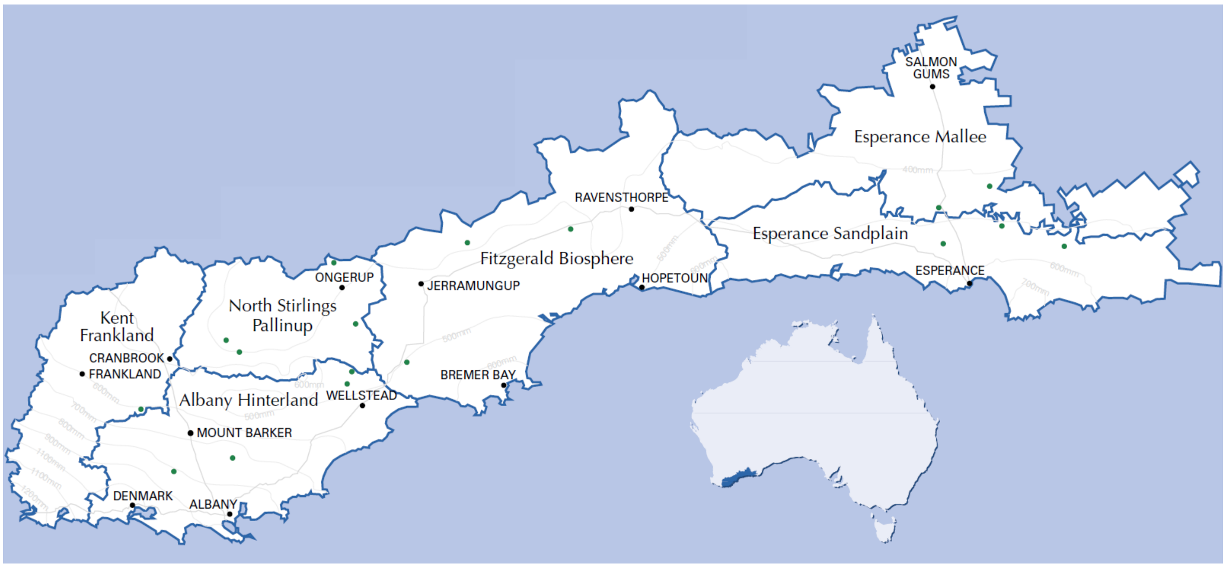

Figure 1: The South Coast region of Western Australia divided into six sub-regions

2.2 Soils

The landscape on the South Coast is dominated by broad undulating plains broken occasionally by incised river and creek systems close to the coast in the western portion of the region and broad flat lake systems in the east. Soils are varied. They can be broadly identifiable by organically stained sandy top soils overlying leached white and yellow sands over weathered clays. Dominant soil groups are sandy duplex with alkaline subsoil, gravelly sandy duplex, deep sandy duplex with gravel and deep sand (>80cm). These soils are characterized by high sand content (up to 95% in the topsoil) of varying size fractions, low silt and clay content and in some cases lateritic gravels. This has implications for the physical, chemical and biological properties of these soil profiles (Master 2013).

2.3 Dominant agricultural systems

The South Coast region is dominated by mixed sheep and cattle grazing and cropping (Master 2013). Common crops grown are barley, wheat and canola with smaller areas of field peas and lupins. No-till systems are common with increasing adoption of precision cropping technology. Sheep enterprises are often a combination of wool and prime lambs with merinos and merino crosses still dominant, though some dedicated meat breeds are growing in popularity.

The very high rainfall zone in the eastern sandplains area is dominated by beef cattle and in some cases sheep production farming systems. Most of these properties are grass fed systems with a dominance of self-replacement herds. There are some properties running predominantly trade stock however they are in the minority. There are some feedlots across the sand plain with most of these handling less than 5,000 head.

In the very high rainfall areas there are small areas of perennial horticulture (grape vines and olives) and annual horticulture focusing on seed potatoes and vegetable production. Blue gum plantations also take up a significant area in the >600mm rainfall zone although areas are contracting.

2.4 Pastures

Pastures play an important role in agricultural enterprises along the South Coast through animal production, improvements to crop rotations, and conserved fodder. Pasture composition depends on soil type and rainfall. The most common pasture species in the South Coast are annual grasses and legumes, dominantly ryegrass and sub clover. Significant areas of mixed ryegrass and serradella pastures, and smaller areas of medics, also exist, generally on the poorer sandy soils. There is approximately 153,000ha of the sub-tropical perennial grass, kikuyu, planted in the very high rainfall areas (especially in areas with more than 600mm of annual rainfall where kikuyu is most likely the dominant pasture along with ryegrass and sub clover), making it the most widely planted perennial in Western Australia (Master 2013).

There are smaller areas of other perennial grasses, legumes and shrubs, with approximately 58,000ha of mixed species across the region. Temperate perennial grasses, including perennial ryegrass, tall fescue and phalaris, can be found in regions with rainfall greater than 600mm. Lucerne pastures are relatively rare, occupying approximately 33,000ha of the South Coast in areas with rainfall less than 500mm where cropping is dominant. There are small amounts of other mixed and single species pasture including chicory, Rhodes grass, setaria and other temperate grasses, generally on poorer soils.

Saltland pastures, such as mixed swards of tall wheat grass and puccinellia, and saltbush are grown in small pockets throughout the South Coast region. They are more commonly found in lower rainfall areas where salinity is evident, although they can be found on non-saline marginal land with higher rainfall. Tall wheat grass can be grown with a minimum annual rainfall of 350mmyear but prefers 450mm or greater. The most common saltbush species include oldman (A. nummularia), river (A. Amnicola) and wavy leaf (A.undulata) (Master 2013). They can be found in very low rainfall arid regions, and higher rainfall zones up to approximately 500mm.

2.5 Resource management issues

The major land resource management issues faced by landholders in the South Coast region include subsoil acidity, water repellence, wind erosion, compaction, waterlogging, secondary salinity and phosphate leaching. Possible causes and solutions/adaptions are presented in in Table 1.

Table 1: Resource management issues and possible solutions/adaptions

Issue	**Cause**	**Solutions/adaptations**
Subsoil acidity	Leaching of nitrates, product removal plus many soils were likely acidic before clearing	Liming at up to 2t/ha (100NV equivalent), delayed and split application of nitrogen, planting of acid tolerant pastures and crops
Water repellence	Tillage, natural occurrence of wax's and oils in the soil.	Application of suitable clay at up to 150t/ha, furrow seeding, soil wetters. Planting of spreading perennial pastures.
Wind erosion	Ground cover falling to below 50% prostrate stubble or 30% standing stubble	No-till, wind breaks, perennial pastures on areas highly susceptible to wind erosion. Management of stock to maintain adequate ground covers.
Compaction	Vehicle movement and livestock	Tramlining, Deep ripping, use of deep rooted perennials (lucerne)
Waterlogging	Shallow clay layers and water tables.	Use of waterlogging tolerant perennials (kikuyu, phalaris, tall fescue), engineering solutions including contour and W banks and raised beds.
Secondary salinity	Excess recharge leading to high water tables.	Use of salt tolerant pastures and shrubs, use of high water use perennials throughout the catchment.
Phosphate leaching	Application of excess phosphorous in low PBI soils	Soil testing and application of correct amounts of phosphate fertilisers, Split application of fertilisers, Use of deep rooted perennials.

Source: Master (2013)

3. Methodology

This economic review of key perennial forage systems on the South Coast of Western Australia includes a summary of relevant literature review to highlight the potential production advantages and disadvantages of each system, pasture productivity, feed nutrient values to livestock, production benefits, production costs (including establishment and maintenance), potential environment impacts, and associated risks.

In additional to the survey of literature, a Cashflow Analysis is conducted using current production and market variables to provide economic information to landholders who may be making production decisions regarding these systems. The Cashflow Analysis is an assessment of the cost-effectiveness and investment value of alternate management systems. It involves summing all the costs associated with the investment, as well as all the benefits of the investment. The difference between the benefits and the costs is the net value of the project. The Cashflow Analysis utilises the well-accepted methodology of discounting the future benefit and cost stream over a time horizon (10 years), using a discount rate, in this case 5%. An Annual Equivalent Profit (AEP) is calculated. The AEP is the annual amount if a constant profit per ha per year could be earned over the 10 years, allowing for interest and tax.

In 2015, a similar economic review was conducted by the author for South Coast NRM to review key land management systems/practices on the South Coast; including annual pasture, perennial kikuyu pasture, perennial native grass pasture, pasture cropping, canola cropping, agroforestry, and soil amelioration through claying (Petersen 2015). The report conducted economic analysis using RIM (a decision tool for integrated management of herbicide-resistant annual ryegrass). The Cashflow Analysis presented in this report uses a similar methodology and assumptions so that economic results are directly comparable across the two reports.

This economic analysis focusses on continuous grazing systems and is conducted for four regions within the South Coast depending on rainfall:

- Low Rainfall Zone (LRZ): < 325mm/year,
- Medium Rainfall Zone (MRZ): 325 - 450mm/year,
- High Rainfall Zone (HRZ): 450 - 550mm/year, and
- Very High Rainfall Zone (VHRZ): > 550mm/year.

If a landholder's location is close to one of the rainfall thresholds above (i.e. close to 325, 450 or 550mm/year), it is recommended that the information from both adjacent regions be considered.

The economic review includes a "business as usual" scenario to compare alternate grazing systems with the dominant grazing system currently used on the South Coast. This is assumed to be annual unimproved pasture. The review also includes a "do nothing" scenario comparing alternate grazing systems with unimproved marginal farmland.

Results derived from the Cashflow Analyses are contingent upon the assumptions driving them and should be interpreted accordingly. The economics of any system is variable, depending on location along the South Coast, as well as seasonal and market conditions. It is recommended that results are considered as indicative only, and that a grower consider further information and their farm-specific variables before adopting any of these systems.

The Cash Flow Analyses do not represent year to year variation in weather or price. Yields in the model vary from year to year due to the sequence of crops and pastures selected. A non-legume crop (wheat, barley or canola) grown after a legume (pulse or legume pasture) is expected to achieve a higher yield than if grown after a non-legume crop or volunteer pasture due to disease break and fixed nitrogen benefits. It is expected that canola or legumes grown after a break of only one year (i.e. after a single year of wheat, barley or canola) will realise a lower than average yield due to the increased risk of disease occurrence.

Assumptions regarding fertiliser and farm-gate prices are provided in Table 2. Other assumptions that differ across focus regions are presented in Table 3.

Table 2: Fertiliser and farm-gate prices (net of selling costs except transport) used in Cashflow Analysis

	Price ($/t)
Fertiliser prices	
DAP/MAP	750
Urea	570
Farm-gate prices (net of selling costs except transport)	
Wheat	270
Barley	275
Canola	460
Legume	270

Sources: AWB (2015,2016) and Glencore Grain (2015,2016).

Table 3: Summary of key assumptions that differ across the four South Coast rainfall regions (5-year averages)

	LRZ	MRZ	HRZ	VHRZ
Average yields (t/ha)				
Wheat	1.5	2.3	2.5	2.0
Barley	1.8	2.4	2.7	2.2
Canola	0.7	1.1	1.2	1.0
Legume	1.0	1.5	1.4	1.2
DAP or MAP rates for cereals (kg/ha) [a]	26	46	52	52
Urea rates for cereals (kg/ha)	40	75	90	90
Other variables				
Stocking rate (DSE/ha)	3	6	9	17
Sheep Gross Margin ($/DSE) [b]	15	27	30	35
Average arable area per farm (ha)	5,500	4,000	2,000	500

Source: Planfarm and Bankwest (20010 - 2016) and discussions with various experts within the Department of agriculture and food, Western Australia (DAFWA)

LRZ = low rainfall zone (< 325mm/year), MRZ = medium rainfall zone (325 – 450mm/year), HRZ = high rainfall zone (450 – 550mm/year), and VHRZ = very high rainfall zone (> 550mm/year)

[a] DAP = Di-ammonium phosphate and MAP = mono-ammonium phosphate

[b] The return expected per dry sheep equivalent, excluding the costs specific to pasture implementation and maintenance.

The results of the indicative standard solution from the Cashflow Analysis for a continuous volunteer pasture in each rainfall zone are summarised in Table 4. This is the "Business as usual" scenario against which the other systems are compared. An annual gross margin is provided for each phase of the pasture sequence over a 10-year time horizon, as well as the equivalent annual profit. These results are relevant on a paddock-scale, rather than a whole-farm scale.

Table 4: Indicative standard solution for a continuous volunteer pasture in the different rainfall zones of the South Coast; including annual gross margins and the equivalent annual profit

Year	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**EAP***
Gross margin ($/ha/year)											**($/ha/year)**
LRZ	-10	10	10	-5	10	10	-5	10	10	-5	**2**
MRZ	40	72	72	58	72	72	58	72	72	58	**67**
HRZ	76	120	120	103	120	120	103	120	120	106	**115**
VHRZ	156	227	227	212	227	227	212	227	227	212	**224**

* The Equivalent Annual Profit (EAP) is the constant annual profit that is equal in value to receiving the variable annual gross margins each year and accounting for interest earned and tax paid.

4. Economic review of land management systems

The economic review of key land management systems is presented in this section as follows:

- 'Business as usual' - Annual unimproved pasture (Section 4.1),
- Kikuyu perennial grass pasture (Section 4.2),
- Saltbush-based forage system with annual pasture understory (Section 4.3),
- Combination of perennial grass and saltbush (Section 4.4),
- Mixed shrub systems with saltbush (Section 4.5), and
- 'Do nothing' - Unimproved marginal farmland (Section 4.6).

4.1 'Business as usual' – Annual unimproved pasture

Native unimproved pastures are still a significant component of the pasture resource in the South Coast of Western Australia, even though large areas have been replaced or modified with improved grasses, legumes and forage crops. Unimproved pasture species along the South Coast are dominated by Vulpia (silvergrass), Barley grass, Annual ryegrass and Brome grass. Fencing off an area and grazing it conservatively can result in significant improvements in groundcover and productivity with minimal cost (fencing only). Once fenced off from grazing, almost all but the most extremely salt scalded areas will revegetate. Areas that suffer severe periods of inundation generally remain bare; just about everything else will grow some kind of plant cover. Annual unimproved pasture is generally a viable option, even if it is not the most profitable one. However, for highly saline or water logged sites, this approach often results in the establishment of samphire, which is not suited to grazing as the salt concentrations in the forage is high.

As the costs associated with unimproved pasture are low, it is a low risk land management option. The most significant risk associated with marginal land is overgrazing. Livestock can be attracted to salt-affected land as it tends to be damp and cool, exacerbating this overgrazing.

The difference in production between improved species and volunteer species gets smaller as sites become more severely affected by salinity and waterlogging. Sown pastures are generally no more productive than volunteer pastures at high salinity and waterlogging.

LWWP and FFICRC (2015) suggest that unimproved pasture (fencing and allowing volunteer pastures to generate) is suited to:

- Farms where the areas of saltland are too small to make a significant contribution to the farm feed supply even if a more productive saltland pasture could be easily and cheaply established,
- Areas where there is significant summer rainfall where salt may be leached down the soil profile that reduces the severity of soil salinity,
- Farms with large areas of saltland,
- Any sites where, after a site assessment, the risk of failure of saltland renovation is thought to be high,
- Sites where available funds allow fencing but not pasture improvement,
- Sites where the landholder does not have the time or skills to establish a saltland pasture, and
- Sites where the decision to sow an improved saltland pasture may be taken at a later date.

While profitability is a major driver of farm businesses, it is of lower consideration in decisions associated with marginal land. This is partly because marginal land is usually a small proportion of a farm area, and also because it can be a significant visual blight on the landscape (especially saltland). Increasing groundcover significantly increases amenity and environmental benefits.

A review of potential productivity advantages and disadvantages of annual unimproved pasture is provided in Table 5.

Table 5: Review of potential productivity advantages and disadvantages of annual unimproved pastures in South Coast farming systems

Advantages	**Disadvantages**
Low-cost source of pasture (only fencing is required). The costs associated with fencing and volunteer pasture are always significantly lower than if a specific saltland pasture is sown.	Low economic returns, poorer animal performance and productivity, poorer feed quality (especially out of season) compared with improved pastures or forage crops.
Less risk of establishment failure compared with annual improved pastures. The likelihood of 'failure' from fencing off and allowing volunteer pasture to establish is almost zero as long as there are desirable species adjacent to the area to act as a seed source.	Limited value in filling the feed gap. As salinity and waterlogging increases, there is a greater requirement for grain feeding.
Implementation is easy compared with improved pasture, planting forage crops or sowing cash crops without precluding a later decision to improve the pasture.	Synchronising peak periods of feed demand for stock with peak periods of annual volunteer pasture growth can be challenging, especially on low-productivity soils and where rainfall limits productivity.
Retention of native plant genetics.	Compared with improved pasture, unimproved pasture generally contains more ryegrass which can contain toxic endophytes causing animal health issues and lower animal performance.
Volunteer species can provide a low-cost but effective feedbase for livestock enterprises.	Livestock may have limited performance when fed pasture with nutrient imbalances including high or low levels of structural or non-structural carbohydrates, crude protein, trace elements and minerals, and the presence of ant-nutritional compounds.
Maintenance of unimproved annual pastures is minimal compared with improved annual pastures, perennial pastures and cropping systems.	Terminating the volunteer pasture phase can be difficult when it contains persistent pasture species.
Compared with unimproved marginal land, unimproved pastures can lead to increased soil organic matter levels, leading to an increase in the level and variety of soil organisms.	Livestock grazing on volunteer pasture may cause soil compaction and pugging on heavy soils.
Compared with unimproved marginal land, unimproved pastures reduce surface soil evaporation, and salt build-up, and make a greater contribution to floral and faunal biodiversity.	

Advantages	Disadvantages
Annual unimproved pastures provide ground cover, reducing the risk of erosion and providing greater water infiltration, potentially preventing running off which can result in soil erosion and sedimentation problems.	
Fencing and allowing a volunteer pasture to establish does not preclude a later decision to sow a pasture on the site.	
Annual unimproved pastures can lead to increased soil organic carbon levels, storing carbon underground and potentially slowing global warming impacts.	
Compared with unimproved marginal land, unimproved pastures increase visual amenity by establishing green and growing plants on saline scalds. Increased visual amenity has been shown to result in increases in rural populations.	

Sources: Bathgate and Byrne (2007), Collett and McGufficke (2005), GRDC (2011), Westwood (2008)

Most publically-available studies on the economics of annual pastures are ten or more years old. Few studies have considered the economics of annual pastures in recent years, and even fewer have considered the economics of annual unimproved pasture. This is largely due to the increased research attention given to perennial pastures, and increased sowing of crops in traditionally grazed areas as a result of reduced economic profitability of livestock relative to crops along the South Coast.

Bathgate and Byrne (2007) estimate that the benefits of volunteer annual pasture in Western Australia, compared with a do nothing scenario, is approximately $15/ha (compared with $90/ha in New South Wales and $60/ha in South Australia). They found this to be lower than the benefit of planting saltbush for forage when farm feed is in short supply (the Autumn feedgap). It also allows improved management on a greater area of marginal land than if expense were spent on pasture establishment. However, cost, effort and risk of volunteer annual pasture are higher compared with the do nothing scenario. Neither option precludes a later decision to improve the pasture, allowing a staging of the total expense over time.

LWWP and FFICRC (2015) have a rule of thumb that volunteer pasture will produce up to half the feed of a sown pasture. Alcock and Hegarty (2006) suggest that stocking rate and also methane production from a farm based on unimproved pastures is about 40 percent of that from a farm based on improved pastures, but the gross margin on the less productive farm is only 25 percent of the more productive farm ($139/ha compared with $545/ha).

Gross margins of annual volunteer pastures are heavily influenced by output prices, the control of feed demand and net pasture production. Feed demand is dependent on stocking rate, lambing date and per head feed demand. Net feed production is the balance between new growth and the senescence of older tissue, which is dependent on soil nutrient levels (nitrogen, phosphorus and potassium), pH, temperature, moisture and drainage (Westwood 2008).

Costs specific to pasture implementation and maintenance for volunteer pasture are generally negligible, especially in the lower rainfall zones. Indicative equivalent annual profit from volunteer annual pasture phases in select crop-pasture rotations and continuous volunteer annual pasture on a per hectare basis (not the paddock or whole farm scale) across rainfall zones is provided in Table 6.

Table 6: Indicative gross margin of volunteer pasture phases under a number of rotations ($/ha/year)

	LRZ	MRZ	HRZ	VHRZ
WBCPv	2	51	87	n/a
CBPvPv	2	57	99	n/a
WPvPvPv	-9	48	91	183
Pv	4	64	111	215

W = wheat, B = barley, C = canola, Pv = voluntary pasture, P = improved pasture in year 1 and then volunteer pasture in subsequent years. Stocking rate is higher in first five years of improved pasture.
n/a = not applicable (rotation not used in that rainfall zone)

The profitability of volunteer annual pastures is dependent on output prices, feed demand and net pasture production. A sensitivity analysis of animal gross margin (which captures fluctuations in output price) and stocking rate (which is an indicator of the paddock's feed demand and net pasture production potential) on the annual equivalent profit of continuous annual volunteer pastures is presented in Table 7. Results for the low rainfall zone show that including continuous pasture rotations in this region has potential to be unprofitable. This reflects reality where landholders rarely use continuous pasture, but are planting unproductive soils to other enterprises such as saltland pasture, saltbush, lucerne and tagasaste. The sensitivity analysis results from the medium, high and very high rainfall zones show significant fluctuations in profitability depending on gross margin and stocking rate, with opportunities for very high profitability of continuous pasture in the very high rainfall zones with high stocking rates and gross margins.

Table 7: Sensitivity analysis on the effect of animal gross margin and stocking rate of continuous annual volunteer pasture on indicative annual equivalent profits ($/ha/year)

		LRZ			**MRZ**		
		Animal Gross Margin ($/DSE)					
		-20%	**Standard**	**+20%**	**-20%**	**Standard**	**+20%**
Stocking rate	**-20%**	-5	-2	1	40	52	64
	Standard	-2	2	6	52	67	81
	+20%	1	6	11	64	81	99
		HRZ			**VHRZ**		
		Animal Gross Margin ($/DSE)					
		-20%	**Standard**	**+20%**	**-20%**	**Standard**	**+20%**
	-20%	71	140	111	141	178	215
	Standard	91	115	140	178	224	270
	+20%	111	91	169	215	270	326

KEY FINDINGS: ANNUAL VOLUNTEER PASTURES

- Native unimproved pastures are still a significant component of the pasture resource in the South Coast of Western Australia, even though large areas have been replaced or modified with improved grasses, legumes and forage crops.

- Costs specific to pasture implementation and maintenance for volunteer pasture are generally negligible, especially in the lower rainfall zones. As these costs are low, it is a low risk land management option.

- The difference in production between improved species and volunteer species gets smaller as sites become more severely affected by salinity and waterlogging.

- Gross margins of annual volunteer pastures are heavily influenced by output prices, the control of feed demand and net pasture production. Feed demand is dependent on stocking rate, lambing date and per head feed demand.

- Annual unimproved pasture is generally a viable option, even if it is not the most profitable one. The exception is in low rainfall zones when output prices and stocking rates are low. The profitability of annual unimproved pasture can be very rewarding in very high rainfall zones when output prices and stocking rates are high.

4.2 Kikuyu perennial grass pasture

Kikuyu is a sub-tropical grass with a deep root system which enables it to use water and nutrients from deeper soil layers than annual plants. It has moderate autumn, winter and spring production, and good summer production. Hence it can extend the pasture grazing seasons in summer and autumn when the production of annual pasture species is generally poor. Kikuyu is very well suited to the conditions of the South Coast of Western Australia - which are characterised by few frosts, cool winters, mild springs, medium to long growing season (6 – 8 months) and warm to hot summers with 25-35% out-of-season rainfall (Moore *et al.* 2006). Kikuyu has proven to be one of the most widely adopted perennial pastures on the South Coast of WA with an estimated area of more than 153,000ha (Master 2013).

A list of the potential productivity advantages and disadvantages of including perennial pastures in South Coast farming systems are provided in Table 8, and their environmental advantages and risks are highlighted in Table 9.

Table 8: Review of potential productivity advantages and disadvantages of including perennial pastures in South Coast farming systems

Productivity advantages	Productivity disadvantages
Out of season green feed, especially in summer.	Higher establishment costs compared with annual pastures, with a time-lag until they can be grazed.
Increased carrying capacity due to improved seasonal distribution of feed and pasture use.	More intensive grazing management requirements to ensure the pastures persist and their quality is maintained.
Potential for the value and optimal area of perennial pastures to increase as the focus of South Coast livestock enterprises shift towards meat production.	Perennial forages use more of the water within the annual crop rooting zone. The drier soil profile at the end of the pasture phase can result in lower yields of following crops.
Ability to reduce or replace supplementary feeding in autumn.	Exacerbated problems with worm control in sheep.
Ability to increase production from land with a low carrying capacity.	Perennial kikuyu pastures become difficult weeds to control in crops.
Ability to turn-off animals at target liveweights all year round.	The 'green bridge' created by perennial kikuyu pastures increases the incidence of pests and diseases in annual crops and pastures.
Reduced wool faults and maintenance of wool fibre diameter and stable strength.	A possible need to change rotations on other soil types to achieve the best enterprise mix.
Reduced fodder conservation.	
Increased winter feed.	
Opportunity to rest annual pasture paddocks after the break of the season.	
Provision of feed during false break events, where annual pastures suffer reduced seed bank.	
Replaced weed burden in pasture due to displacement by perennials.	

Sources: Byrne (2006), Master (2013), Moore (2006) and Sanford (2010).

Table 9: Review of potential environmental advantages and risks of including perennial pastures in South Coast farming systems

Environmental advantages	Risks
Increased water use and reduced deep drainage to groundwater, and therefore reduced risk of dryland salinity or waterlogging.	Establishment failure or poor establishment.
Maintenance of plant cover in summer to reduce wind erosion. Kikuyu pastures maintained more than 50% ground cover through summer and autumn, even in the driest years.	Failure to survive a dry summer.
Overcoming water repellent soils by creating preferred pathways which move water into the soil profile that can subsequently be used for plant growth.	Can overwhelm native plants, particularly around creek lines. Care should be taken to manage kikuyu in these circumstances to maintain environmental and production benefits.
Increased perennial cover for waterways.	
Slowing the rate of soil acidification via a reduction in nitrate leaching.	
Perennial pastures are generally expected to store more soil carbon than annual pasture due to their extensive root system which persists all year round.	

Sources: Byrne (2006), Master (2013), Moore (2006) and Sanford (2010).

Economic review of perennial pastures indicates that gross margins of perennial pastures is heavily influenced by the rainfall zone and area of perennial pasture in the system, and have significant impacts on stocking rate, optimal lambing time and supplementary feeding required. A review of the literature of these impacts is provided in Table 10. Key economic findings are as follows:

1. Inclusion of perennial kikuyu pastures can increase gross margins by 5-10% in the higher rainfall zones of the South Coast (650mm/year) to 400% in the lower rainfall zones (350mm/year),
2. The optimal area sown to perennial kikuyu pastures depends on the livestock enterprise and the mix of perennial pastures,
3. On average, the optimal area of the farm sown to kikuyu is approximately 45% of grazing area, although the proportion is higher in the medium rainfall zones (75%) than the very high rainfall zones (25%),
4. Profit can be insensitive to kikuyu area within a significant range, especially where a mix of perennial pastures is used to provide a range of feed availability due to their different seasonal growth patterns,
5. The inclusion of perennial kikuyu pastures allows an increase in stocking rate (20 – 30%), pasture use and pasture growth, and
6. Perennial kikuyu pastures help fill the summer/autumn feed gap and so reduce the amount of supplementary feeding required per animal by approximately 50 – 100%.

Table 10: Review of economic benefits from perennial pastures

Factor affecting gross margin	Economic review
Area sown to perennial pasture	**Master (2013):** • For an average farm on the South Coast, gross margin can increase by approximately $100/ha/year (or 45%) when 25% of the grazing system is based on kikuyu with a stocking rate of 8DSE/WG[a] ha, • In a medium rainfall environment (370mm/year), it is optimal to have a higher proportion of kikuyu in the pasture base (75%) which can lead to an average 65% increase in gross margin at a stocking rate of 4 DSE/WG ha, • In a very high rainfall environment (650mm/year), smaller proportion of kikuyu (25%) in the pasture base are optimal, leading to a 5 - 10% increase in gross margin with a stocking rate of 12 DSE/WG ha, **Young *et al.* (2004):** • Compared with a system of 70% annual pasture and 30% crop, sheep gross margins can increase by 300% (from $10/ha/year to $30/ha/year) if kikuyu replaces 45% of farm that would otherwise be in annual pasture, **Masters *et al.* (2006):** • Compared with a system of 70% annual pasture, a system of 25% annual pasture and 45% kikuyu can increase sheep gross margin by 400% (from $10/ha/year to $40/ha/year), **Stanford and Young (2005):** • Compared with a system of 70% annual pasture, a system of 23% annual pasture and 47% kikuyu can increase sheep gross margin by 115% (from $32/ha/year to $69/ha/year), **McDowall *et al.* (2003):** • Replacing an annual pasture mix with a kikuyu-annual pasture mix on deep sands near Esperance can increase the gross margin of a cattle enterprise by 20%.
Rainfall zone	• Sanford (2013) found that including 25 – 75% kikuyu in South Coast systems can increase whole-farm gross margins by approximately 80% in the medium rainfall zone, 50% in the high rainfall zone, and 13% in the very high rainfall zone.
Stocking rate	• On average, stocking rate can lift from 6.5 to 8.0 DSE/WG ha when kikuyu is introduced. However, the risk of financial loss in some years was also increased with this higher stocking rate. Also, this stocking rate is highly dependent on rainfall zone (Master 2013), • Young *et al.* (2004) and Masters *et al.* (2006) report an annual change in stocking rate of 8.1 to 10.7 DSE/WG ha. • McDowall *et al*. (2003) report a carrying capacity of 0.64 cows/ha for the annual pasture compared with 0.55 cows/ha for the kikuyu mix.
Optimal lambing time	• The optimal lambing type for perennial kikuyu pasture systems with >75% perennials was June or July in relatively high rainfall areas and May in relatively low rainfall areas (Master 2013).
Supplementary feeding	• Kikuyu typically reduce supplementary feed costs. When supplementary feeding is required, kikuyu is able to tolerate high stocking rates and prevents soil erosion (Master 2013), • Young *et al.* (2004) and Masters *et al.* (2006) report a decrease in

Factor affecting gross margin	Economic review
	supplementary feeding from 18.5kg/DSE to 8.3kg/DSE, • McDowall *et al.* (2003) found that the increase in growth margin of a kikuyu mix pasture with an annual pasture is largely due to the elimination of in supplementary feeding costs (from $19/ha/year).
Enterprise type	• Sanford (2013) found that the value of perennial kikuyu pastures depended significantly on the type of livestock enterprise. For example, a prime lamb enterprise on annual pasture could support a stocking rate of 11 DSE/ha whereas a fine wool enterprise could support a stocking rate of 12 DSE/ha. Gross margins ranged from $50/ha/year for fine wool to$500/ha/year with prime lamb (depending on the cost structure). Perennial pastures were able to increase these gross margins by $50 – 200/ha/year.
Establishment cost	• Perennial kikuyu pasture establishment costs vary with different species and economies of scale. It is estimated that the cost of establishing kikuyu sown at 1kg/ha is $110 - $190/ha based on the following assumptions: o Chemicals: 0 – 40kg/ha o Kikuyu seed: $40 – 60/kg o Contract seeding: $45 – 65/ha o Own gear: $30 – 90/ha These costs should be annualised over the life of the sward (e.g. approximately 30 years for kikuyu) (Master 2013). The above costs do not include lost grazing time during establishment (usually 6 months) and the cost of any additional fertiliser above normal maintenance to establish the sward.

[a] DSE/WG ha = dry sheep equivalent per winter grazed hectare

Current indicative profitability of a perennial kikuyu pasture paddock is presented in Table 11. This profitability assumes a kikuyu establishment cost of $130/ha/year and fertiliser costs after establishment (to encourage the annual components of the kikuyu sward) of $30/ha/year in the very high rainfall zone and $10/ha/year in the high and medium rainfall zones. These results assume that stocking rate increases above the standard (see Table 3) by 25% in the second and subsequent years after establishment. Indicative equivalent annual profit is $65/ha/year in the medium rainfall zones, increasing to approximately double for the high rainfall zone ($126/ha/year) and double again for the very high rainfall zone ($242/ha/year). On a per hectare basis, this compares favourably with continuous annual volunteer and improved pasture in the high and very high rainfall zones. On a whole-farm basis, this profitability will depend on the percentage of crop and pasture in the system, which is not considered in this analysis.

Table 11: Indicative equivalent annual profit ($/ha/year) for perennial kikuyu pasture compared with continuous annual pasture

	MRZ	HRZ	VHRZ
Continuous perennial pasture	65	126	242
Continuous annual volunteer pasture	67	115	224
Continuous annual improved pasture	54	111	239

A sensitivity analysis on profitability given a 20% increase and decrease in animal gross margin and stocking rate is shown in Table 12.

Table 12: Sensitivity analysis on the effect of gross margin per DSE and stocking rate on indicative gross margin of continuous kikuyu perennial pastures ($/ha/year)

		MRZ			HRZ			VHRZ		
		Animal Gross Margin ($/DSE)								
		-20%	Standard	+20%	-20%	Standard	+20%	-20%	Standard	+20%
Stocking rate	-20%	31	46	61	71	95	120	138	184	231
	Standard	46	65	83	95	126	157	184	242	300
	+20%	61	83	105	120	157	194	231	300	370

KEY FINDINGS: PERENNIAL KIKUYU PASTURES

- Perennial kikuyu pastures have two key benefits:
  - they have a deep root system which enables them to use water and nutrients from deeper soil layers than annual plants, and
  - they can extend the growing season at both ends when conditions are favourable.
- Kikuyu is very well suited to the conditions of the South Coast of Western Australia and has proven to be one of the most widely adopted perennials on the South Coast of WA.
- Economic review of perennial pastures indicates that the gross margin of kikuyu pasture is heavily influenced by the rainfall zone and area of perennial pasture in the system. Kikuyu has significant impacts on stocking rate and supplementary feeding required.
- Profitability of kikuyu paddocks starts at $65/ha/year in the medium rainfall zones, and approximately doubles for the high rainfall zone ($125/ha/year) and the very high rainfall zone ($240/ha/year). This is approximately $10 and $20/ha/year more than annual volunteer pastures in the high and very high rainfall zones, respectively, and is similar to improved pastures in the medium rainfall zone.
- On average, the optimal area of the farm sown to kikuyu is approximately 45% of grazing area, although the proportion is higher in the medium rainfall zones (75%) than the very high rainfall zones (25%).

4.3 Saltbush-based forage systems with annual pasture understory

Approximately 2.7%, or 82,000ha, of the South Coast region in Western Australia is affected by salinity (van Gool *et al.* 2008). This means that salinity at or near the soil surface is causing a reduction in plant growth, water quality and/or damage to infrastructure. A loss of pasture production of salt sensitive species (such as clover) and reduced or failed crops leaves the ground exposed to wind and water erosion and the invasion of salt-tolerant weeds (such as barley grass, button weed and samphire). High salt levels lead to nutrient imbalances or deficiencies, soil structure decline and a range of environmental problems such as saline waterways that affects aquatic life (Cunningham and Sargeant 2013).

Saltbush (*Atriplex species*) is a halophytic shrub (a shrub adapted to living in salty soil) which is commonly planted on salt-affected land in Western Australia. The most common saltbush species include Old Man saltbush (*Atriplex nummulariam*, which supports slightly better animal performance and lower risk of spreading across into the alleys than other species) and River saltbush (*Atriplex amnicola*, which tends to be more tolerant of transient waterlogging than other species). Saltbush is capable of creating an environment for good understory growth and provides out-of-season feed to livestock that is a rich source of vitamin E.

Saltbush can be established with direct seeding, the planting of seedlings, or both (LWWP and FFICRC 2015). Direct seeding is a lower cost option compared with planting seedlings, but has a higher risk of poor establishment. Before establishment, the ground is generally mounded, and the saltbush is seeded/planted into the mound. The use of a niche seeder that creates an M-shaped mound with the seed (and vermiculite) or seedling planted in the groove or niche on top of the mound, has proven very effective.

Saltbush and understory species is now the option most recommended for saline sites with low to medium rainfall. The saltbush and understory provide different functions. The role of the understory is to provide feed for livestock in as greater quantity and nutritive quality as possible, and to ensure that the saltland site has good groundcover to minimise the evaporation of water from the soil and the subsequent build-up of salts in the root zone. It provides the bulk of the feed for grazing animals. The saltbush provides green feed in Autumn (when otherwise there would be only dry standing feed), and uses water over summer to dry out the soil and lower the water table so that salt in the surface soil can be leached readily. Drawing down the water table by just 20-30cm has a significant impact on the productivity of the soil (LWWP and FFICRC 2015).

The climatic requirements for the under-storey species are less specific than for saltbush, so the sites recommended for this system are restricted to areas where saltbush is suited. The suitable rainfall range for saltbush stands is approximately 250 – 450mm. For areas with rainfall levels below 250mm, production potential decreases significantly and there is high risk of establishment failure. For areas with rainfall levels above 450mm, there is high likelihood of waterlogging which is a significant constraint to saltbush productivity. Saltbush prefers warm sites with approximately 300 – 400mm of rainfall. Saltbush tends to perform better on lighter soils, compared with heavy clays, and sail acidity is only a minor inhibiting factor unless at extreme levels. The most restricting soil issue for saltbush is waterlogging.

Saltbush is sown in multiple rows with wide alleys between the sets of rows for the understory. This reduces the cost of saltbush plantings and allows easier vehicle access and livestock management. Early published information about saltbush focussed on dense plantings of at least 1,000 saltbush stems per hectare. However, this presents a challenge for vehicle access and livestock mustering. Now, dense saltbush planting are only recommended for saltland sites with high summer salinity (subsoil EC_e values of 8-16dS/m). Now, it is recommended that saltbush be planted at 500-600 stems per hectare, although this can vary widely depending on the width of the alleys.

Simply allowing an understory to establish from volunteer species is an option, but it tends to be dominated by sea barley grass with lower nutritive quality to than other potential species. A mixture of improved species is generally the best option. The best species are those that grow best in low summer soil salinities but which tolerate moderate summer salinity levels. Depending on location and rainfall, the recommended annual species are legumes such as balansa clover, sub-clover and burr medic, or grasses such as annual ryegrass.

A list of the potential productivity advantages and disadvantages of including saltbush-based forage systems with annual pasture understory in South Coast farming systems are provided in Table 13, and their environmental advantages and risks are highlighted in Table 14.

The economics of saltbush and annual understory have not been well documented. There is some evidence that the profitability of saltbush and annual understory can be substantially higher than dense saltbush plantings because of the lower establishment cost and higher carrying capacity. Indicative estimates of the cost of establishing and maintaining a saltbush and annual understory system in the low to medium rainfall areas of the South Coast are provided in Table 15. Establishment costs are estimated to be approximately $410/ha and maintenance costs approximately $60/ha.

The benefits to the livestock enterprise include additional green feed grazing opportunities for approximately 120days/year with a stocking rate of approximately 20DSE/ha. Indicative cumulative returns through time are shown in Figure 2, suggesting that the system breaks even during year 4.

Over the 10 year period of this analysis, the indicative annual equivalent profit is approximately $28/ha/year. However, this estimate is sensitive to animal gross margin (which captures fluctuations in output price) and stocking rate (which is an indicator of the paddock's feed demand and net pasture production potential) (Table 16). Results of the sensitivity analysis suggest that saltbush and annual understory has the potential to be unprofitable with low stocking rates and low gross margins (output prices). However, even under these adverse conditions, there are still significant benefits from revegetating marginal land as articulated in Table 14. Profitability is of lesser importance on saline land compared with more productive agricultural land.

Table 13: Review of potential productivity advantages and disadvantages of including saltbush–based forage systems with annual understory in South Coast farming systems

Advantages	Disadvantages
Increased productive use of salt-affected land through increased water use over summer to dry out the soil and lower the water table so that salt in the surface soil can be leached readily. Drawing down the water table by just 20-30cm has a significant impact on the productivity of the soil.	Salt may be exported from the site in the first couple of years, caused by the soil disturbance associated with pasture establishment.
Provision of out-of-season green feed for livestock leading to increased sheep production from greater year-round forage opportunities.	Saltbush and annual understory is restricted to low to medium rainfall zones. In higher-rainfall areas, the ability of the saltbush to reduce the amount of salt entering into the root zone of the more shallow-rooted under-storey species and to leach salt from the surface is restricted.
Increased availability of land for livestock during the cropping season.	The under-storey is more vulnerable to failure than saltbush because it has to persist from year to year or re-establish each year which is difficult in sites with higher salinity levels.
Saltbush is a source of Vitamin E, which is not present in dry feed, preventing the need for licks or drenches. Two weeks on saltbush will take Vitamin E deficient sheep up to a standard level of Vitamin E, which increases meat quality.	Higher establishment costs and risk of failure than unimproved pastures.
Creates opportunities for delayed grazing of other pastures after the autumn break.	More intensive grazing management is required compared with saltbush only, to ensure the pastures persist and their quality is maintained.
Significant dry matter production of annual understory when saltbush rows are sown in wide alleys.	Plantings on a significant scale are required to get production and whole-farm flexibility benefits.
Can dry out the soil profile to create a buffer zone that enables winter rain to leach salt out of the surface soil.	
Established saltbush stands are very hardy, resisting drought, salinity and frost. Unless weakened by waterlogging (especially over summer), then persistence of saltbush stands is usually good.	
Compared with saltland pasture options, saltbush with pasture under-storey can provide a substantial windbreak that gives shelter to stock, potentially improving lambing percentages and survival rates in off-shears sheep.	
There is significant visual amenity value in a stand of well-managed saltbush and understory, especially compared with bare and untreated saltland.	

Sources: Cunningham and Sargeant (2013), Herbert (2006), FFICRC (2014), LWWP and FFICRC (2015) and van Gool *et al.* (2008)

Table 14: Review of potential environmental advantages and risks of including saltbush–based forage systems with annual understory in South Coast farming systems

Environmental advantages	Risks
Increased water use and reduced deep drainage to groundwater, and therefore reduced risk of dryland salinity or waterlogging.	Establishment failure or poor establishment of saltbush, due to too low rainfall or waterlogging.
Maintenance of plant cover in summer to reduce wind erosion.	Young saltbush plants, especially if direct-seeded, are very susceptible to weed competition.
Enhanced flora and fauna diversity by providing habitat to small local birds, lizards and other small animals.	Poor establishment of understory (lack of rain, weed competition, too salty or waterlogged, insects) .
There is some evidence of improved microbial activity in soils established to saltbush with understory compared with bare areas.	Saltbush plants can grow out of the reach of grazing sheep if they are not grazed hard at least annually.
Increased soil organic carbon levels compared with annual pastures alone, storing greater quantities of carbon underground and potentially slowing global warming impacts.	The combination of saltbush and under-storey must be effectively grazed, with the possible need for some supplementary feeding, to maximise understory production and persistence.
	Risk of damage by pests. Rabbits and kangaroos find saltbush palatable and can do damage to seedlings. Locusts can defoliate saltbush. Saltbush established by direct seeding is vulnerable to red-legged earth mite (*Halotydeus destructor*).

Sources: van Gool *et al.* (2008), Cunningham and Sargeant (2013), LWWP and FFICRC (2015) and Herbert (2006)

Table 15: Indicative estimates of the cost of establishing and maintaining a saltbush and annual understory system in the low to medium rainfall areas of the South Coast

Activity	Description	Annual cost ($/ha)	
Pasture seeding		100	Year 1 only
Ground preparation for saltbush		10	
Saltbush seeding	Contract direct seeding: $50/km @ 4km/ha	200	Year 1 only
Vermiculite	$15/100L bags; 1.5bags/ha	22	Year 1 only
Weed control		20	Year 1 only
Fertiliser for annuals		60	Every year
Total establishment cost		**412**	**Year 1 only**
Total maintenance cost		**60**	**Year 2 onwards**

Source: Farmer and author estimates

Figure 2: Indicative cumulative net returns of a saltbush and annual understory system in the low to medium rainfall areas of the South Coast

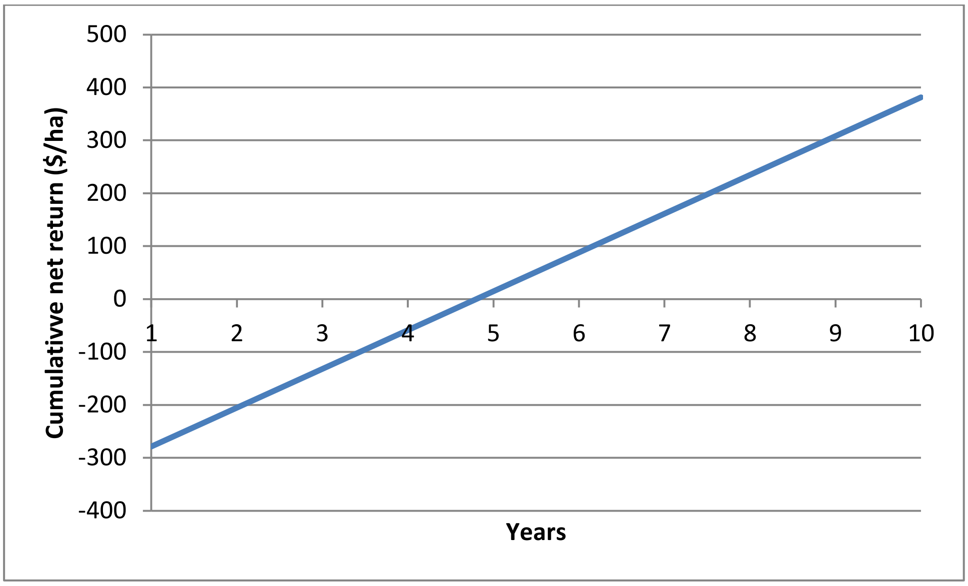

Table 16: Sensitivity analysis on the effect of animal gross margin and stocking rate on indicative annual equivalent profits of a saltbush and annual understory system in the low to medium rainfall areas of the South Coast ($/ha/year)

		Animal Gross Margin ($/DSE)		
		16 (-20%)	**20 (Standard)**	**24 (+20%)**
Stocking rate (DSE/ha)	**5.0 (-20%)**	-26	-6	14
	6.7 (Standard)	1	28	54
	8.0 (+20%)	22	54	86

KEY FINDINGS: SALTBUSH-BASED FORAGE SYSTEMS WITH ANNUAL PASTURE UNDERSTORY

- Saltbush and annual understory is now the option most recommended for saline sites with low to medium rainfall.

- The role of the understory is to provide the bulk of the feed for grazing animals. The saltbush provides green feed in Autumn when otherwise there would be only dry standing feed.

- The most common saltbush species planted on salt-affected land on the South Coast include Old Man saltbush (*Atriplex nummulariam*, which supports slightly better animal performance and lower risk of spreading across into the alleys than other species) and River saltbush (*Atriplex amnicola*, which tends to be more tolerant of transient waterlogging than other species).

- The climatic requirements for the under-storey species are less specific than for saltbush. The suitable rainfall range for saltbush stands is approximately 250 – 450mm.

- The economic benefits to the livestock enterprise is additional green feed grazing opportunities for approximately 120days/year with a stocking rate of approximately 20DSE/ha. Establishment costs are approximately $400/ha and maintenance costs are approximately $60/ha.

- Over a 10 year period, the system breaks-even in about the fourth year after establishment and the indicative annual equivalent profit is approximately $28/ha/year. However, these estimates are sensitive to livestock output price and stocking rate. Saltbush and annual understory has the potential to be unprofitable with low stocking rates and low output prices.

- There are significant production and environmental benefits from revegetating saline land that makes profitability of lesser importance on saline land compared with more productive agricultural land.

4.4 Combination of perennial grass and saltbush

An alternative to establishing an annual pasture understory in saltbush-based forage systems is the establishment of a perennial pasture understory. This is often the preferred approach in land which is highly saline and cannot support a strong annual pasture understory.

Saline sites are often variable, and so a mixture of perennial pasture species can be a good option. A description of salinity classes is provided in Table 17, and suggested perennial pastures species for each salinity class are provided in Table 18. Saltbush is generally planted on soils of salinity Class 2 and 3, in alleys with salt tolerant perennials in the inter-rows. For soils of Class 2, generally producers will sow the entire paddock to tall wheat grass first and then create the mounds and plant the saltbush. For soils of Class 3, options are more limited with puccinellia-based pastures along with dense saltbush stands the preferred option. Establishment may be slow, so weed control is important and fencing is critical to allow these sites to establish.

Table 17: Interpretation of Soil EC with respect to clay content

Class	Salinity hazard	Effect on plant growth	EC of 1:5 soil / water extract (dS m^{-1})				
			Sand /loamy sand	Loam	Sandy clay loam	Light clay	Heavy clay
1	Non-saline	Negligible effect	< 0.15	< 0.17	< 0.25	< 0.30	< 0.40
2	Slightly saline	Very sensitive crops affected	0.16 – 0.30	0.18 – 0.35	0.26 – 0.45	0.31 – 0.60	0.41 – 0.80
3	Moderately saline	Many crops affected	0.31 - 0.60	0.36 – 0.75	0.46 – 0.90	0.61 – 1.15	0.81 – 1.60
4	Very saline	Salt tolerant plants grow	0.61 – 1.20	0.76 – 1.50	0.91 – 1.75	1.16 – 2.30	1.61 – 3.20
5	Highly saline	Few salt tolerant plants grow	> 1.20	> 1.50	> 1.75	> 2.30	> 3.20

Source: Patterson (2006)

Table 18: Suggested perennial pasture species for each salinity class

Pasture species	Salinity class
Kikuyu	1 - 2
Puccinellia	2 - 4
Rhodes grass	1 - 2
Strawberry clover	1
Tall fescue	1
Tall wheat grass	1 - 3

A combination of perennial grass and saltbush has similar production advantages and disadvantages, environmental advantages and risks as a combination of annual grass and saltbush (see Tables 13 and 14), with the following exceptions:

1. Perennial pastures are generally expected to store more soil carbon than annual pasture due to their extensive root system which persists all year round,
2. Saltbush forage systems with perennial understory have great management requirements compared with an annual understory. The nutritional value of perennial grasses is highest when they are rotationally grazed and not allowed to get rank. However, saltbush is not ideal for rotational grazing and needs at least six months to recover after heavy grazing (FFICRC 2014). Priority can be given to the perennial pastures and re-seeding saltbush when necessary. Establishing saltbush from seed obtained on-farm, rather than nursery-raised seedlings, facilitates this, and
3. There are greater nutritive benefits of saltbush forage systems with perennial understory compared with an annual understory. Saltbush has a low fibre and high crude protein content, but too much salt and sulphur. This is a complement for perennial grasses as they tend to have high fibre, low crude protein and sulphur levels, and negligible salt. The crude protein, sulphur and salt in saltbush are beneficial for wool growth (FFICRC 2014).

Few economic studies have considered the economic viability of combining perennial grasses with saltbush. Herbert (2006) calculated costs and returns from 21 case study projects from the Western Australia Producer Network component of the Sustainable Grazing on Saline Lands program(SGSL) using a discounted cash flow investment analysis framework. Project sites analysed were established during the dry years of 2002 to 2005. Results for those sites with saltbush and perennial understory in or near the South Coast are provided in Table 19. Herbert found that profitability was most strongly influenced by the costs of establishment in interaction with subsequent productive performance. There was a large range of establishment costs reflected by the wide range of site locations, methods used and plant species seeded. Highest risk of failure and low profitability occurred in the low rainfall areas, although some successes were evident. The best successes were in the medium rainfall districts where there is a greater selection of suitable pasture species and potential for high grazing days production.

Indicative estimates of the cost of establishing and maintaining a saltbush and perennial understory system in the low to medium rainfall areas of the South Coast are provided in Table 20. Establishment and maintenance costs are estimated to be approximately $380/ha and $35/ha, respectively. The benefits to the livestock enterprise is estimated to be additional green feed grazing opportunities for approximately 120days/year with a stocking rate of approximately 15DSE/ha (assuming less productive land capacity compared with an annual understory). Indicative net returns in year one is approximately -$280/ha and net returns thereafter is approximately $65/ha, with the farm breaking even in year 5 (Figure 3).

Over the 10 year period of this analysis, the indicative annual equivalent profit is approximately $21/ha/year. However, this estimate is sensitive to animal gross margin (which captures fluctuations in output price) and stocking rate (which is an indicator of the paddock's feed demand and net pasture production potential) (Table 21). Results of the sensitivity analysis suggest that there is less risk of the system being unprofitable, compared with saltbush and annual understory as there is less costs associated with perennials. This is a significant outcome given that land utilised for saltbush for perennial understory is usually more salt-affected and therefore marginal compared with the same system and an annual understory. However, there is also less potential for high returns in times of high output prices and stocking rates.

Table 19: Summary of costs and benefit cost ratios from select case study projects from the Western Australia Producer Network component of the Sustainable Grazing on Saline Lands program(SGSL)

Location	Rainfall average (mm)	Pasture mix	Area (ha)	Revegetation cost including fencing and water supplies ($/ha)	Revegetation cost excluding fencing and water supplies ($/ha)	Benefit cost ratio (including fencing and water supplies)	Benefit cost ratio (excluding fencing and water supplies)
Broomhill	432	Mix of tall wheat grass, lucerne, balansa, puccinellia, wavy leaf saltbush, old-man saltbush, river, Rhodes grass, kikuyu, signal grass and Bambatsi panic	49	254	254	2.55	2.55
Jerramungup	370-400	Saltbush and puccinellia/tall wheat grass	36	394	323	1.28	1.54
Katanning	325	Saltbush and tall wheat grass/puccinellia, Rhodes grass, Gatton panic and lucerne	40	595	321	.88	1.57
Tambellup	388	Saltbush, Lucerne and evergreen saltland pasture mix	19	531	282	1.06	1.84
Quairading	350	Saltbush and annual/perennial understory (strawberry and balansa clovers, medics and safeguard ryegrass)	9	476	365	0.61	0.78 Not profitable but stopped the increase of salinity

Source: Herbert (2006), SGSL (2006a-e)

Table 20: Indicative estimates of the cost of establishing and maintaining a saltbush and perennial understory system in the low to medium rainfall areas of the South Coast

Activity	Description	Annual cost ($/ha)	
Pasture seeding	1kg/ha @ $90/kg	90	Year 1 only
Ground preparation for saltbush		10	
Saltbush seeding	Contract direct seeding: $50/km @ 4km/ha	200	Year 1 only
Vermiculite	$15/100L bags; 1.5bags/ha	22	Year 1 only
Weed control		20	Year 1 only
Fertiliser for perennials		35	Every year
Total establishment cost		**377**	**Year 1 only**
Total maintenance cost		**35**	**Year 2 onwards**

Source: Farmer and author estimates

Figure 3: Indicative cumulative net returns of a saltbush and perennial understory system in the low to medium rainfall areas of the South Coast

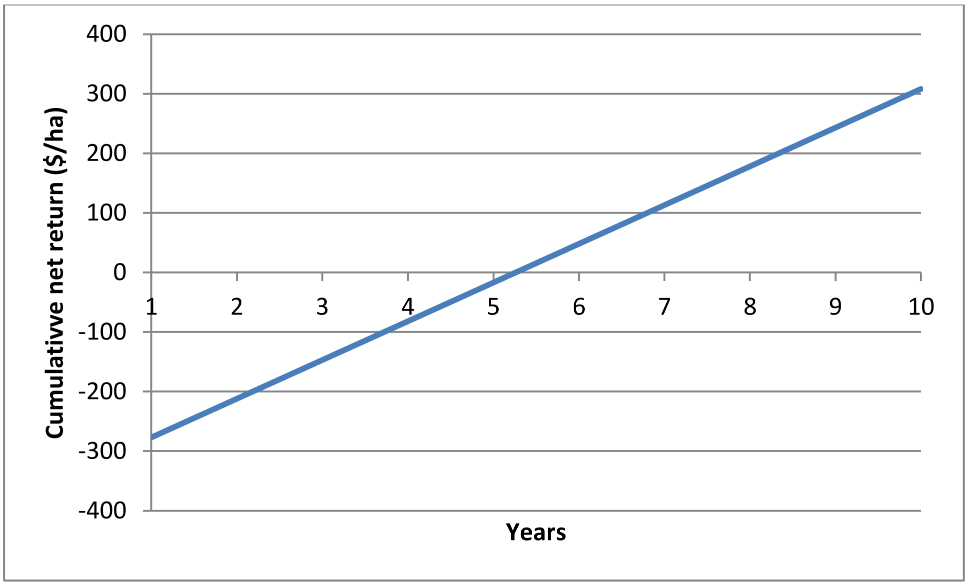

Table 21: Sensitivity analysis on the effect of animal gross margin and stocking rate on indicative annual equivalent profits of a saltbush and perennial understory system in the low to medium rainfall areas of the South Coast ($/ha/year)

		Animal Gross Margin ($/DSE)		
		16 (-20%)	**20 (Standard)**	**24 (+20%)**
Stocking rate (DSE/ha)	**4.0 (-20%)**	-15	1	17
	5.0 (Standard)	1	21	41
	6.0 (+20%)	16	41	65

KEY FINDINGS: COMBINATION FO PERENNIAL GRASS AND SALTBUSH

- Saline sites are often variable, so saltbush-based forage systems with a mixed perennial pasture understory can be a viable option, especially on moderate to highly saline land.
- Saltbush-based forage systems with a perennial pasture understory have similar production advantages and disadvantages, environmental advantages and risks compared with an annual pasture understory. However, a perennial pasture understory is generally expected to store more soil carbon, have greater management requirements and can have greater nutritive benefits than an annual pasture understory.
- The economic benefits to the livestock enterprise of saltbush forage systems with perennial understory is additional green feed grazing opportunities for 15DSE/ha for approximately 120days/year.
- Establishment costs are approximately $380/ha and maintenance costs are approximately $35/ha, with breakeven expected in year 5.
- Over a 10 year period, the indicative annual equivalent profit is approximately $21/ha/year, which is sensitive to output prices and stocking rate.
- A saltbush-based forage system with a perennial pasture understory is expected to have less opportunity for high profits but less risk of being unprofitable, compared with a saltbush and annual understory, as there are fewer costs associated with perennials compared with annuals. The is a significant outcome given that land utilised for saltbush for perennial understory is usually more salt-affected and therefore marginal compared with the land used for saltbush and annual understory.

4.5 Mixed shrub systems with saltbush

The adoption of perennial forage shrubs, both indigenous and introduced species, in saline agricultural landscapes can provide significant production and environmental benefits. They can increase the area of productive land, improve nutrient cycling and carbon sequestration in poor soils and provide a source of nutrient to livestock at key times of the year to overcome feed gaps (Toovey *et al.* undated). In the previous two subsections, we have focussed on saltbush-based forage systems. LWWP and FFICRC (2015) note that other species, like blue bush and particularly quailbrush, can be planted as mixes with River and Oldman saltbush along the South Coast region. CSIRO and South Coast NRM are conducting research into revegetation of saline sites with a mixture of shrub species as listed in Table 22.

Table 22: Mixed shrub species currently being trialled by CSIRO and South Coast NRM

Species	Common name
Maireana brevifolia	Small leaved bluebush
Enchylaena tomentosa	Ruby saltbush
Rhagodia preissii	Mallee saltbush
Atriplex nummularia	Old man saltbush
Atriplex amnicola	River saltbush
Atriplex rhagodioides	Silver saltbush
Eremophila glabra	Tar brush
Chenopodium nitrariaceum	Nitre bush

Toovey *et al.* (undated) found that sheep grazing mixed shrub systems with saltbush were relatively heavier compared with sheep grazing stubble. Enteric methane emissions were 36% higher, but when expressed as emission intensity, emissions from the shrub plots were approximately 50% lower per unit of weight gain. Mixed shrub forage systems provide increased protein and vitamin intake to sheep, and volunteer grasses in the inter-rows provide improved digestibility and feed conversion efficiency compared with stubble. Toovey *et al.* (undated) conclude that *"The revegetation of saline agricultural landscapes in Western Australia has the potential to significantly increase livestock production without major increases in the enteric methane emissions, reduce the impact of 'feed gaps', provides direct on-farm environmental benefits and the potential opportunity for the land manager to participate in the carbon economy."*

Research into mixed shrub systems with saltbush is still in its infancy. A small number of farmers on the South Coast are trialling this system but to the author's knowledge, no landholders have embarked on adoption beyond these trials. The economic viability of these systems has not been tested. It is likely that mixed shrub systems with saltbush will have similar production advantages and disadvantages, environmental advantages and risks as outlined in the previous two sections (depending on whether the understory is dominated by annual or perennial pastures). Anecdotal evidence suggests that the production benefits of mixed shrub species are not as high as systems dominated by traditional species of saltbush only. So as yet, the economic benefits are expected to be lower than those outlined in the previous two subsections. However, this has not been proven and in time, mixed shrub species selection may result in systems with increased economic profitability.

KEY FINDINGS: MIXED SHRUB SYSTEMS WITH SALTBUSH

- Mixed shrub systems may include blue bush, quailbrush, tar brush, nitre bush and several species of saltbush.
- Mixed shrub systems are currently in trial phase along the South Coast of Western Australia, with no full-scale adoption known to the author.
- The adoption of perennial forage shrubs, both indigenous and introduced species, in saline agricultural landscapes may increase the area of productive land, improve nutrient cycling and carbon sequestration in poor soils, and provide a source of nutrient to livestock at key times of the year to overcome feed gaps.
- Early research shows that mixed shrub systems with annual understory provide increased protein and vitamin intake, and improve digestibility and feed conversion efficiency compared with sheep grazing stubble.
- The production advantages and disadvantages, environmental benefits and risks of this system are expected to be similar compared with those articulated in earlier subsections regarding saltbush-based forage system with pasture understory.
- The economic viability of these systems has not been tested. Anecdotal evidence suggests that current mixed shrub species as yet do not achieve the economic benefits currently achieved by saltbush-only forages, although this has not been proven.

4.6 'Do nothing' – unimproved marginal farmland

Where soil is marginal due to high-levels of salinity or waterlogging, the most economic use for the land may be to do nothing; except perhaps fence it to prevent grazing. This option is similar to volunteer pasture but excludes grazing as a management tool. This has the advantage of being relatively low-cost and low-risk compared with other more pro-active options, and if sheep are excluded from the site, it includes benefits of improvements in groundcover and land rehabilitation. It allows volunteer revegetation to decrease soil erosion with the potential to mitigate severe flash flooding, and will generate an increase in amenity values (the desirability of that land).

Sites that are most likely to be fenced and excluded from grazing are those suited to the growth of samphire (*Halosarcia* species) (LWWP and FFICRC 2015). Production of samphire is maximised where there is high subsoil salinity and low depth to the watertable - areas which are almost permanently waterlogged and too wet for saltbush to persist. This includes salt lakes and pans, salt marshes and coastal flats, and areas of secondary salinity when waterlogging associated with high water tables become an issue. Samphire should not be grazed as the salt (ash) concentrations in the leaves are too high.

Natural revegetation of highly saline or waterlogged sites is gradual and episodic. Germination on bare areas can be improved by disc pitting or creating furrow to trap seed and moisture. Other species may also colonise, such as curly ryegrass, cotula and glasswort. Stands of trees may colonise on sandy rises, especially *Casuarina obesa*. A list of the potential advantages and disadvantages of unimproved marginal farmland on the South Coast is provided in Table 23.

Marginal land is only left unimproved where the land has no commercial value, other than perhaps future industries such as fixation/sequestration of soil carbon or the production of glycine betaine from samphire. It is used on land where medium to long-term crop or pasture production is likely to fail, resulting in negative returns. Economic analysis suggests that a 'do nothing' scenario may be the best economic alternative if wheat yields are lower than approximately 0.8 – 1t/ha, stocking rates are less than approximately 1.2 – 2.7DSE/ha or if stocking rates for saltbush with perennial pasture is less than 12 DSE/ha, depending on the rainfall zone and market prices (see Table 24).

Table 23: Review of potential advantages and disadvantages of unimproved marginal farmland in South Coast farming systems

Advantages	Disadvantages
Reduced risk of economic loss due to a failed crop or pasture	There is no commercial value to be gained from 'doing nothing' although this is generally only considered on sites where salinity and waterlogging is so sever as to exclude any commercial options
A stand of samphires will stabilise sites, making them less susceptible to water erosion	If livestock are kept on adjacent land, there is a fencing cost associated with excluding livestock
Mounds of sand around the bases of samphire (produced during episodes of wind erosion) ban slow surface water flows to decrease the severity of flash flooding	It is unlikely that species that grow on unimproved marginal land will have any remediation services to the land as can be associated with some other saltland alternatives which may increase water use, water table draw down and reduce salt accumulation
Seeds of samphires of the genus *Tecticornia* are still harvested and eaten by Aboriginal people to make into a type of cake	
Increase in biodiversity value associated with a salt-tolerate plant ecosystem is superior to that of a bare, untreated saline scald. This is especially the case as samphire is endemic and therefore not found in other countries	
Provision of a wildlife refuge for kangaroos and other native animals.	
Improved amenity value in naturally revegetated marginal land compared with bare and untreated saltland	

Sources: Datson (2005) and LWWP and FFICRC (2015).

Table 24: Indicative break-even yields for wheat or various pasture species, below which a 'do nothing' scenario may be best

Rainfall zone	**Indicative break-even yield**		
	Wheat (t/ha)	Stocking rate for volunteer pasture (DSE/ha)	Stocking rate for saltbush forage system with perennial pasture (DSE/ha)
Low	0.8	2.7	12[a]
Medium	0.9	1.5	12[a]
High	1.0	1.4	n/a
Very high	1.0	1.2	n/a

n/a = not applicable (rotation not used in that rainfall zone)
[a] This is the stocking rate for intensive grazing during part of the year. Divide by 3 to obtain average year-round stocking rate.

KEY FINDINGS: ‘DO NOTHING’ – UNIMPROVED MARGINAL FARMLAND

- Where soil is marginal due to high-levels of salinity or waterlogging, the most economic use for the land may be to do nothing; except perhaps fence it to prevent grazing.

- This has the advantage of being relatively low-cost and low-risk compared with other more pro-active options, and if sheep are excluded from the site, it includes benefits of improvements in groundcover and land rehabilitation.

- Marginal land is only left unimproved where the land has no commercial value, other than perhaps future industries such as fixation/sequestration of soil carbon or the production of glycine betaine from samphire.

- Economic analysis suggests that a ‘do nothing’ scenario may be the best economic alternative if wheat yields are lower than approximately 0.8 – 1t/ha, stocking rates are less than approximately 1.2 – 2.7DSE/ha or if intensive stocking rates for part of the year on saltbush with perennial pasture is less than approximately 12 DSE/ha, depending on the rainfall zone and market prices.

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