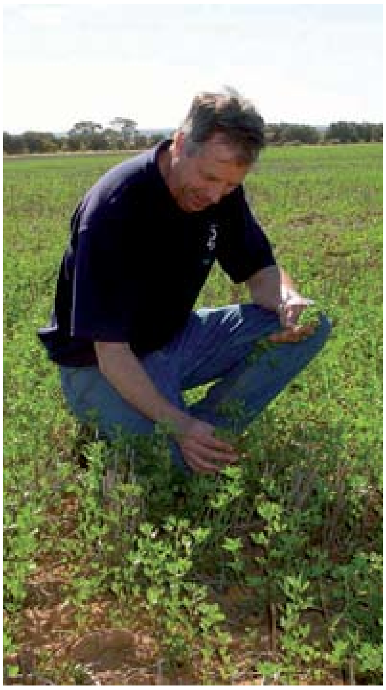
SALTLAND SOLUTIONS

– options for saltland restoration



FUTURE FARM INDUSTRIES CRC

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Published by: Land & Water Australia

Postal address: GPO Box 2182, Canberra, ACT 2601
Office Location: L1, The Phoenix, 86 Northbourne Avenue, Braddon, ACT 2612
Telephone: 02 6263 6000
Facsimile: 02 6263 6099
E-mail: land&wateraustralia@lwa.gov.au
Internet: www.lwa.gov.au

Publication Data: Saltland solutions – options for saltland restoration
Product code: PN22064
ISBN: 978-1-921544-29-3

This report was developed from content from the Saltland Genie website (www.saltlandgenie.org.au) by:
Mike Wagg – Jarrapool Project Management and Consulting Pty Ltd
Gabrielle Sheehan – Currie Communications Pty Ltd

The majority of the development work for the Saltland Genie website was conducted by:
Warren Mason (RPS Solutions), Bruce Munday (Clear Connections), Gabrielle Sheehan (Currie Communications Pty Ltd), Ed Barrett-Lennard (Department of Agriculture and Food, Western Australia [DAFWA]/Future Farm Industries Cooperative Research Centre) and Nick Edwards (South Australian Research & Development Institute [SARDI]/FFI CRC).

In addition, the following people made significant contributions through collating, writing or editing components of the 11 Saltland Solutions:

- Elizabeth Abraham, SARDI Livestock & Farming Systems
- Ed Barrett-Lennard, DAFWA
- John Bartle, Department of Environment WA
- Luke Beange, NSW Department of Primary Industries
- Andrew Craig, SARDI
- Nick Edwards, SARDI
- Justin Hardy, DAFWA
- Don Loch, Queensland Department of Primary Industries
- Malcolm McCaskill, Department of Primary Industries, Victoria
- Craig Liddicoat, Rural Solutions SA
- Geoff Moore, DAFWA
- Phil Nichols, DAFWA
- Hayley Norman, CSIRO Livestock Industries
- Paul Sanford, DAFWA
- Bill Semple, NSW DPI (retired)

Layout by: Substitution Pty Ltd
Printed by: BigPrint

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Introduction

An expansion of saltland knowledge

After a decade of minimal activity, the first few years of the 21st Century saw a major surge in research and development associated with the management and rehabilitation of saltland. This effort was stimulated by four key factors:

- National Dryland Salinity Program – An external review of the NDSP indicated that insufficient attention in that program had been directed to managing saltland.[1]
- National Land & Water Resources Audit – In 2000 the NLWRA reported that there will continue to be significant saline areas in every State and that every State's salinity strategy should address the issue of 'living with salinity'.[1]
- CRC for Plant-based Management of Dryland Salinity – In 2001 The CRC Salinity was established with a primary research focus on reducing recharge but with a significant mandate to boost R&D of saltland management.
- Land, Water & Wool – From 2002 to 2007, the wool industry, through Australian Wool Innovation Ltd, established and funded Land, Water & Wool, a five-year natural resource management (NRM) program managed by Land & Water Australia. The program, with State and national partners, invested several million dollars into saltland management via the SGSL (the Sustainable Grazing on Saline Lands) initiative.[1]

This combination of factors and investments resulted in saltland research sites in every southern State and more than 120 farmer-managed demonstration/research sites, generating a huge amount of information on options for managing salinity that cover a range of different objectives and environments.

This publication has been created out of the main project synthesising saltland knowledge – the **Saltland Genie** website (www.saltlandgenie.org.au).

The creation of Saltland Genie

The Saltland Genie website brings together the latest findings and conclusions about saltland management to provide the most reliable recommendations that are available.

The website is the 'supermarket' for anyone shopping for saltland knowledge. It has been designed specifically to take advantage of the power of web delivery, with everything the 'shopper' might need, including a 'shop assistant' – the Genie – to direct you down the right 'aisle' and link you up the most appropriate information.

Though useful for a wide range of audiences, the Saltland Genie website has been designed with four particular audiences in mind – information-seeking farmers, farm advisers, catchment managers and researchers/students.

This publication contains much of the technical information available in Saltland Genie and is designed for people who prefer to use hard copy references. It lacks some of the navigational power of 'the genie' and reference will be made to additional information that the website provides that is not available in these pages.

The Saltland Genie website contains additional saltland information.

Tackling a difficult problem

There is a long history of new pasture species and improved management techniques resulting in significant increases in productivity on 'normal' grazing land. In addition, traditional thinking on dryland salinity management was based almost entirely on recharge reduction. This is being overturned as some of the negative side effects, such as reduced fresh water flows and associated declining water quality in streams, have become apparent. With the recent string of dry years across the southern States, salinity in many catchments has stabilised instead of expanding, as often occurred until the late 1990s. This has moved the focus from recharge reduction to halt the spread of salinity towards discharge management of now well-defined and stable areas.

Until relatively recently, saltland was largely neglected by graziers and researchers as it appeared to offer few rewards. Recent research and on-farm trials across Australia have given a real boost in the confidence with which saltland can be tackled and the impact this can have on achieving improved resource condition.

Throughout the 1980s and 1990s a small number of enthusiastic researchers and farmers persisted with saltland management and began to show how saltland could make a significant contribution to productive farming systems.

Their results,[2] combined with the increasing incidence of salinity across southern Australia, caused a re-think in research priorities. The result was a major new effort, with co-ordinated research and trials, particularly through the *Sustainable Grazing on Saline Lands* initiative, part of the national Land, Water & Wool Program.[2] This has improved our understanding of which saltland pastures grow best in what conditions, and how to establish and manage them. It has also greatly improved our knowledge of animal performance on these pastures and how saltland can be integrated into existing farming systems. Importantly, it has also quantified the costs and benefits of these options.

Making worthless land profitable

Traditionally, graziers have focused their management effort on pastures growing on the best available land. It has been there that the greatest gains have been made from pasture improvement through species selection, fertiliser application, weed control and grazing management.

This principle still makes a lot of sense; in most cases the financial returns to be made from an investment in saltland will be lower than from a similar investment in non-saltland. However, some profit from previously unproductive land, while at the same time creating other benefits (such as environmental and social as outlined on the opposite page) is a powerful motivation for improving the management of saltland. Farmer case studies strongly demonstrate this.[3]

Until recently, salinity and waterlogging were often seen as intractable problems that were very costly to address (for example, through engineering works) or unlikely to deliver significant rewards for effort. However, we can now approach many of these situations with confidence that there are suitable pastures and practical management tools to use, all based on good science and/or well-documented experience.

However, 'improving' saltland does require a different mindset to addressing most other soil problems. Whereas acidic, sodic and non-wetting soils respond to ameliorants such as lime, gypsum and clay, saltland soils are usually best addressed by establishing specific plants that are well adapted to the conditions. The questions then become: which plants, how and where to establish them, and how should they be managed? Specific information on the economics of different approaches to saltland management is given in each of the 11 'saltland solutions' that make up the bulk of this publication.

Gaining environmental benefits

Well-managed saltland pastures provide groundcover and it is this groundcover that gives most of the proven environmental benefits:

- Groundcover (particularly critical over summer) limits evaporation from the soil surface. Evaporation from bare saltland is a major factor in concentrating salts in the soil and increasing the salinity of the site.
- Saline sites are often highly unstable and prone to erosion, and groundcover is a critical component of erosion prevention.

In addition, there are some environmental benefits that are not as certain – either because of site differences or because research has not yet supported anecdotal evidence. These include:

- In some regions, saltland pastures lower the watertable, potentially slowing the spread of salinity and making the site more suitable for more productive but less salt-tolerant plants.
- Where saltland pastures replace overgrazed and bare saltland sites, biodiversity is expected to increase. SGSL research provides some support for this through an increase in the number and diversity of flora and fauna present on revegetated saline sites.[4]
- Saltland pastures are expected to reduce salt wash-off from saline sites into nearby streams. This wash-off is the source of much of the salt that is carried from dryland agricultural catchments into down-stream waterways. Research has shown that salt wash-off initially increases when a saltland pasture is established because of the disturbance to the site – however, over a 2-3 year period, there is a substantial reduction.[6]

"Five years ago I would never have dreamed that we could turn such apparently useless land into something so good. Not only that, but we are now able to take sheep out of the stubble paddocks before they start to do damage there. I just wish we had started this 20 years ago, but I am pleased to be doing this now for the next generation. Our success with saltland pasture has encouraged us to also fence off three lagoons and allow them to regenerate as wetlands for wildlife."
– John Kroemer, South Australia

Pride from renovated saltland

Few landscapes appear as desolate as those that are severely affected by salinity and waterlogging. Even from the air, saltland can appear 'desperate' and a symbol of past management practices that have gone wrong. Mildly affected saltland invariably looks unthrifty and neglected – a visible indicator of less-than-ideal farm management that no farmer wants to have 'on show'.

Because many farmers have only small areas of saltland (nationally 50% of woolgrowers with saltland reported having less than 20 ha; in NSW and Victoria 50% of farmers with saltland had less than 10 ha), it is often pride rather than economics that provides the primary motivation to improve saltland. The recognition that it can also be profitable often follows.

Farmers who have restored saltland by protecting it from grazing or who have established or renovated salt and waterlogging-tolerant pastures take great pride in their achievements. This was clearly demonstrated through a photography competition run by SGSL.[5]

Ed Barrett-Lennard, John Kroemer, Glenn Gale and Geoff Kroemer inspect a puccinellia pasture on the Kromer's property .

Photo: Bruce Munday

Better recommendations

Recent research has filled many of the knowledge gaps and added confidence to recommendations. Trials and investigations undertaken through the 120 SGSL Producer Network trials have added a very practical dimension to the knowledge gained and provided regional relevance. There has been a research site, farmer trial or farmer case study in every region across southern Australia where saltland occurs.[6]

One of the very clear messages from the SGSL initiative is that the motivation to improve management of saltland varies greatly from farmer to farmer. Some are driven by the production potential and are therefore focused on the economics, some by a desire to prevent the further spread of salinity, while others are far more concerned about overcoming what they see as a real eyesore on their farm. Management options are now available for all saltland – the key is understanding the capability of this land and making the best choices for it.

Treating saltland is difficult due to its great variability from region to region, from farm to farm and even within a single paddock. The particular option that is best for a saltland site is influenced by biophysical conditions such as soil type and properties, climate, and the types and concentrations of salts present. Socio-economic factors such as the individual situation of a farming enterprise, catchment priorities and previous experience with saltland management will also shape decisions on which options might suit a particular site.

The evidence is now strong that saltland pastures can:

- improve on-farm production and profit – though usually to a lesser extent than similar investments in non-saltland;
- greatly improve the amenity of saltland;
- increase water use from saltland, reducing accessions to the watertable and, in some cases actually drawing down the watertable;
- increase groundcover on saline sites and therefore provide significant reductions in erosion and improved conditions for biodiversity; and
- reduce salt movement from saltland sites into streams.

It is now clear that in most catchments, managing discharge (or saltland) sites should be a higher priority than has historically been the case.[7]

Chapter 1

Saltland Basics

Causes of dryland salinity

Inland Australia is a salty place. All rain brings in small amounts of salt – typically 20 to 50 kilograms per hectare per year across the agricultural regions. Because of our relatively low rainfall and relatively flat landscape, it can take a long time (sometimes tens of thousands of years) for that salt to get carried back to the ocean via our rivers. When plants use the rainwater, they leave the salt behind in the landscape – sometimes in massive amounts. As an example, drilling at Merredin in the WA wheatbelt showed that the soil profile contained about 650 tonnes of salt per hectare or 33,000 times the annual amount deposited in rain. This salt was in the landscape when European settlers arrived with their annual crops and pastures that would disturb the hydrological balance and start to mobilise the stored salt.

The first clear evidence of the link between clearing of native vegetation and the appearance of dryland salinity was gathered by a Western Australian railway engineer, Walter Ernest Wood. In 1924, he published a paper, *Increase in salt in soil and streams following the destruction of native vegetation*, in the Journal of the Royal Society of Western Australia. Wood noted that the native forests and grasslands originally found across southern Australia used nearly all the rainfall. However, when these were cleared by farmers to grow crops and pastures, some rainwater percolated into the soil profile, and the groundwater rose towards the soil surface bringing with it the salt stored in the soil profile. When the watertable reaches about two metres from the soil surface, salt begins to move into the plant root zone, and plant growth and survival became affected.

The long time lag between clearing and the evidence of salinity, and the vast spatial separation often experienced between cause (the areas of the landscape where water infiltrates) and effect (the areas of the landscape where salinity occurs) proved a barrier to a full appreciation of the consequences of widespread land clearance.

More recently, additional causes of dryland salinity (especially transient salinity) have been associated with overgrazing and a decline in soil health.

Right: NSW SGSL Committee members inspecting newly sown pasture. Photo: John Powell

Different types of salinity

There are several types of saltland in Australia, characterised by their various causes.

PRIMARY SALINITY

There are many areas that were already saline at the time of European settlement – perhaps as much as 30 million hectares either along the coastline or in the rangelands and the arid interior. In other words, most of the saline areas in Australia are 'natural' and not the result of agricultural activities.

SECONDARY SALINITY

Secondary dryland salinity can be directly attributed to human activity – principally clearing of native vegetation for annual crops and pastures, and the subsequent soil degradation. Some of the classic signs of secondary salinity include dead remnants of vegetation that grew on the site before it became saline, colonisation by salt-loving species, and increases in waterlogging and inundation, with fences disappearing into saline lakes.

It can be difficult to determine whether a particular saline site represents primary or secondary salinity. In many situations, primary salinity has expanded as a result of agricultural activity, further confusing the issue.

Secondary dryland salinity is caused by three main processes:

Rising watertables

The lower water use of annual crops and pastures compared to the native vegetation they replace often leads to water draining below the root zone, where it becomes part of the groundwater mixing with the salt stored in the soil profile. The watertable then rises, bringing stored salt to the soil surface. When this salt reaches the root zone it inhibits plant growth and survival and the site has become affected by dryland (or seepage) salinity. This has been the most widely accepted cause of dryland salinity in southern Australia. It was the subject of most of the research undertaken through the National Dryland Salinity Program and formed the basis for the Salinity Audit in 2000.

Follow that watertable. Photo: J. Workman

Transient salinity

There are increasing areas of 'dryland salinity' being identified that are not the result of rising saline groundwater bringing salts into the root zone. Transient salinity was first identified in the 1940s and is sometimes called 'magnesia' patches. It is the result of the seasonal movement of salt into and out of the soil profile. Evaporation from the soil surface concentrates the salts in the root zone, from where they are subsequently leached out by rainfall. This type of salinity may occur when the upper layers of soil are sodic, severely restricting the downward movement of water and leading to the formation of a perched watertable. When transient salinity, concentrated by evaporation, occurs within the root zone of crops it can be detrimental to their growth.

Irrigation salinity

Excessive irrigation can lead to locally elevated watertables which, in time, can result in soil salinity if the irrigation water is slightly salty. This is particularly the case if annual rainfall is insufficient or if the subsoil is so impermeable that the salt cannot leach deeper into the soil profile.

Irrigation salinity is a problem for agriculture and horticulture, and also affects parks, gardens and sporting fields in urban areas. Modern irrigation practices have helped reduce the incidence of irrigation salinity, but there are many situations where irrigators are forced to adopt more salt-tolerant crops, pastures or turfs. Salt- and waterlogging-tolerant turf grasses are being actively sought for urban areas where irrigation salinity occurs.

Groundwater flow systems

Catchment characterisation based on groundwater flow systems has proved a particularly important tool for regional planning of responses to salinity, especially in relation to understanding the timeframe and distances over which a catchment might respond. The system is not as effective at the sub-catchment or property scale because of the complex nature of the recharge-discharge process and the lack of local groundwater data that might shed light on the local drivers and processes.

Hydrologists categorise catchments on the basis of the distances over which groundwater moves to cause salinity problems.

Local groundwater flow systems typically have recharge and discharge areas within a few kilometres of one another. They tend to occur within individual catchments in areas of higher relief such as foothills to ranges. They generally respond rapidly to increased groundwater recharge and show dryland salinity within a decade of clearing. They can also respond relatively rapidly to salinity management practices, and afford opportunities to mitigate salinity at a farm scale.

Intermediate groundwater flow systems are between local and regional systems, generally within individual catchments but sometimes flowing between smaller subcatchments. They tend to occur in valleys, typically extend for 5-10 kilometres, and have a greater storage capacity and higher permeability than local systems. They take longer to 'fill' following increased recharge. Increased discharge typically occurs within 50 to 100 years of the native vegetation being cleared. The extent and responsiveness of these groundwater systems present much greater challenges for dryland salinity management than local groundwater flow systems.

Regional groundwater flow systems generally occur in areas of low relief such as alluvial plains. They may have aquifers thicker than 300 metres, and the distances between recharge and discharge areas may be separated by 50 or more kilometres. They have a high storage capacity and permeability. They take much longer to develop increased groundwater discharge than local or intermediate flow systems – probably more than 100 years after clearing. The full extent of change may take thousands of years. The scale of regional systems is such that farm-based catchment management options are ineffective in re-establishing an acceptable water balance. These systems will require widespread community action and major land use change to secure improvements to water balance.

Salinity statistics

The first comprehensive assessment of the national extent of dryland salinity in Australia was undertaken as part of the National Land & Water Resources Audit (NLWRA) in the late 1990s and published in 2000.[2] Table 1.1 indicates the distribution of this risk across agricultural land.

These figures relate only to the hazard of salinity as defined by the groundwater recharge/discharge model – that is, salinity that is caused by rising saline groundwater within the landscape as a result of increased recharge following land clearing and subsequent discharge down slope.

The NLWRA used the best science available at the time and represented a real breakthrough in raising awareness of the extent of salinity, the salinity hazard and the possible risks. However, science moves on and this information, which underpinned much of the initial planning for salinity management, continues to be reviewed and updated using new and better modelling based on the latest data and longer trends.

It is now generally agreed that the total area at risk from salinity in Australia is probably less than that estimated by the Audit – partly due to the limitations of the original models and partly because rainfall across southern Australia has been consistently below average since the estimates were made. However, it is important to note that the Audit did not include transient salinity which is now accepted as an additional and widespread form of secondary salinity. State-by-State updates were prepared for the National Dryland Salinity Program in 2006.[8]

Table 1.1: Salinity risk by State for 2000 and 2050 from the National Land and Water Resources Audit.

STATE	At High Risk Year 2000 (ha)	At High Risk Year 2050 (ha)
WA	3,552,700	4,181,700
VIC	555,000	1,170,000
NSW	161,000	526,570
SA	326,000	421,000
QLD	65,000	Not determined
TAS	53,000	69,500
TOTAL	4,712,700	6,369,000

Recognising dryland salinity

SIGNS AND SYMPTOMS

Saltland areas are much easier to rehabilitate before the salinity and waterlogging become severe and reduce the options available, so early identification is a great benefit. There are a range of indicators (signs or symptoms) that may appear if dryland salinity is affecting a site – some of the most common, starting with the earliest, include:

- changes in crop health, with patches of poor growth;
- changes in pastures, with a tendency to lose legumes and become increasingly dominated by grasses;
- tendency for a site to be wetter than the rest of the paddock, and possibly remain green further into summer when other annuals have died off;
- soil becoming darker;
- noticeable tree decline or patches of unthrifty grasses and shrubs;
- sheep starting to graze these areas preferentially because of the salt content;
- salt-tolerant plants (indicator species) starting to colonise;
- bare and 'scalded' patches appearing, exacerbated by overgrazing; and
- a white salt crust appearing on the soil surface in summer when the soils are dry.

Some of these indicators are not always easy to detect and may take several years before being really noticeable. Some might be indicators of issues other than (or as well as) salinity – for example, bare areas may be caused by acidic soils and tree dieback may be the result of other factors such as pest and disease attacks.

Salinity or waterlogging?

Dryland salinity has two different impacts on plants: an osmotic (drought) impact as salt in the soil makes it increasingly difficult for plants to take up water, and a toxic impact where the salt, once taken up into the plant, slows down plant functions.

Prolonged waterlogging results in less oxygen being available to plant roots. Salinity is often found together with waterlogging, as both stresses are generally associated with elevated watertables.

Waterlogging increases the susceptibility of plants to salt damage by causing the plant roots to become more permeable to salt, so that salt uptake into the shoots is vastly increased. To successfully grow in many saline situations, plants have to be tolerant of both waterlogging and salinity.

The series of photographs below show how the combined effect of salinity and waterlogging has a much harsher effect on plant growth, compared to salinity on its own.

In each photograph, the two pots of wheat on the left are waterlogged while the two pots on the right are freely drained with (a) no salt, (b) salt equivalent to 4% sea water, and (c) salt equivalent to 20% sea water.

a.

0% sea water.

b.

4% sea water (2 dS/m).

c.

20% sea water (12 dS/m).

Saltland indicator plants

Saltland indicator plants can be of great value in diagnosing land affected by dryland salinity, however perennial plants might be indicating a previous salinity/waterlogging problem rather than the current situation. Because plants grow in response to the combined impact of salinity, waterlogging and other site constraints, they can be the most useful 'indicators' of the site's potential. At the very least, they can complement direct measurements of soil salinity and depth to groundwater.

Plants fall into three broad groupings with respect to salinity tolerance:

- halophytes (such as marine couch, puccinellia and saltbush);
- salt-tolerant non-halophytes (such as barley and barley grass); and
- salt-sensitive non-halophytes (such as most legumes).

Figure 1.1 shows the typical responses to salinity. The absolute values of salt in the graph do not matter – more significant are the relative differences:

- Halophytes actually grow *better* on sites with low salinity than on non-saline sites. They are key components of saltland pastures. They will persist in soils of high to extreme salinity.
- Non-halophytes *vary* in their tolerance to salt. The more tolerant species will survive soils with low and even moderate salinity and may therefore be components of saltland pastures. The less tolerant species will be sensitive to soils of low salinity and will therefore almost certainly not be components of saltland pastures.

To assist farmers and others to identify indicator plants and saltland pasture species, the SGSL (Sustainable Grazing on Saline Land) initiative developed *SALTdeck* – a series of plastic-coated cards with photographs and descriptive information for the 50 most common saltland species – both saltland pastures and indicator plants. SALTdeck cards can be viewed individually on the Saltland Genie website or they can be ordered from the Land, Water & Wool website.[9]

The case for preventing recharge

Most land affected by secondary dryland salinity in Australia is caused by the planting of agricultural crops and pastures which use less water than the previous native vegetation. The rainfall in excess of crop and pasture use leaks below the root zone (recharging the groundwater system) and causing saline groundwater to rise. At low points in the landscape this saline groundwater might come close enough to the soil surface to enter the root zone or even discharge directly at the surface.

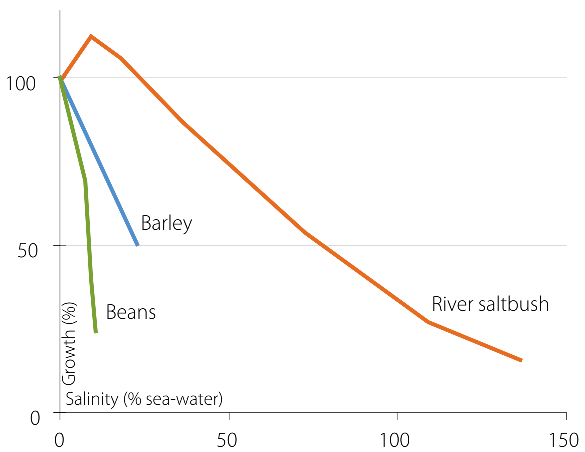
The predominant emphasis of research and management during the 1990s and early 2000s was to reduce this recharge, thereby preventing dryland salinity by removing the cause of the rising groundwater.

When rain falls on a paddock, there are essentially three things that can happen to it.

- Some will be stored in the plants, on the soil surface or in the soil itself and then eventually evaporated back into the atmosphere either directly or through plants.
- Some might leave the paddock as surface run-off.
- Some might seep through the soil beyond the plant's roots until it reaches the watertable and so recharges the groundwater.

This is a very simple definition of the 'water balance', and much more comprehensive analyses of recharge and its impacts on catchment hydrology are available in the NDSP 2006 Update.[10]

Figure 1.1: Response of three plant species to increasing levels of salinity. River saltbush (a typical halophyte) can grow at more than 100% sea-water. Barley (a tolerant non-halophyte) and beans (a sensitive non-halophyte) are much less able to grow as salinity increases.



Recharge can occur virtually everywhere (including on discharge areas), as agricultural systems based on annual species rarely use all the rainfall. However, recharge is much more likely when annual rainfall is high and winter dominant (reducing evaporation); the surface soils are permeable; the landscape is relatively flat; the rooting depth of crops and pastures is shallow; there are no impermeable layers (rock or heavy clay) to prevent the drainage reaching the watertable; and long fallows are used. Though every catchment is different, significant recharge is often associated with fractured rock systems or with deep alluvial sands, rather than with more fertile soils that are often found lower in the landscape.

Not all recharge is bad – indeed, some is essential, particularly when the groundwater has low salinity. Recharge replenishes groundwater systems that provide base flow into rivers and creeks so that they flow between rainfall events. Recharge also provides the water that replenishes Australia's artesian basins. However, when the water balance is upset so that recharge exceeds the natural outflow of the water from the groundwater system, flooding may result. When the groundwater is saline, this discharge can have even more serious consequences for stream water quality, for pastures and crops, and for native bushland, riparian vegetation and wetlands.

What plants reduce recharge?

The native vegetation prior to European settlement was ideally suited to preventing excessive recharge; the climate and the vegetation had established a balance over a long time. While seasonal conditions (particularly rainfall) varied from year to year, the water balance was essentially stable and watertables did not rise or fall significantly. In landscapes receiving less than 900 mm per year, the native vegetation systems allowed very little recharge and only occasional run-off. Replacing the native vegetation with annual crops and pastures upset this balance; large-scale revegetation would eventually restore the ability of those catchments to prevent excessive recharge. However, this environmental gain would be very slow to materialise and would be impose enormous economic and social costs.

Commercial or farm forestry can generally make use of as much of the rainfall as the native bushland, but the dramatic reduction in the volume of fresh surface water flows can be a serious issue in some catchments. Furthermore, farm forestry options are only likely to be profitable in high (and occasionally moderate) rainfall zones.

Of the widely used, agriculturally important species, only lucerne approaches the recharge prevention ability of native bushland and commercial forestry. However, there are real limits to the proportion of a farm over which the growth of lucerne will be profitable. The CRC Salinity has identified those areas of southern Australia where lucerne has agronomic potential and has determined the optimal economic levels of adoption for different farm enterprises.[11]

The vast majority of agriculturally important crops and pastures are annuals that only use water from late autumn to late spring, rather than year-round. This is the primary cause of the increased recharge across the landscape. Perennial pastures, based on either introduced (e.g. phalaris, cocksfoot, fescue) or native grass species provide some recharge control and can be can be utilised on a landscape scale, at least on grazing properties where the groundwater flow system is local.

Positive outcomes?

There are, in fact, few examples of positive catchment scale outcomes from interventions that aimed to reduce recharge. This is partly because, in some cases, it took decades for salinity to appear and a similar time, at least, can be expected before the problem is reversed. The time lag is effectively greater because salt-affected land seldom returns completely to its unaffected condition.

The main difficulty is that recharge occurs over large areas in most catchments, so that large areas of perennial vegetation need to be established to intercept recharge if a significant reduction in total catchment recharge is to occur. Even this would need to be matched with patience to wait, in some cases for hundreds of years, to fully see the desired result.

In the Denmark River Catchment on the South Coast of WA, large-scale, profit-driven adoption of blue gums has transformed the region and reversed salinity trends in the river, but there are few other cases to match this. In this case, the area had a high rainfall, and was close to a port so the widespread adoption of farm forestry was viable. Furthermore, as mentioned above, the impact of forestry on run-off water can be a serious detriment to catchment health.

Given that few perennial options are commercially viable, there are few examples of catchments that have had sufficient intervention to have a material impact on the catchment water balance. The CRC Salinity and the Future Farm Industries CRC were established largely to overcome this lack of commercial options.

At the individual farm level, however, there are many examples of positive outcomes where the groundwater systems are small and local, so that the recharge is adjacent to the discharge, and the time between action to reduce recharge and the impact on discharge is relatively short. *SALT Magazine* has featured many of these, including some where quantitative data appear to support the claim.[12] However, in the absence of controlled experiments, it is difficult to confidently differentiate between the impact of recharge abatement tactics and factors such as other land use practices, the impacts of climatic change, and influences elsewhere in the catchment.

Trees help to control recharge.

Difficulties with reducing recharge

Reducing recharge has major emotional appeal – it deals with the cause rather than the symptom, and it fits well with sustainability and the general notion of restoring landscapes to a less damaged condition. Who would not want to overcome salinity or 'win the war' against salinity? Unfortunately, there are four significant problems with the approach:

- Vegetation options that reduce recharge (lucerne, forestry, native bushland) also reduce run-off – in fact they usually cause a greater reduction in run-off than in recharge. This has a range of economic and social impacts, from dry dams on farms through to impacts on urban communities and other agricultural systems that rely on drawing water from rivers and steams. Major urban and irrigation industries and infrastructure have been built up on the expectation of significant, good quality surface water flows. Recharge management cannot proceed independently from consideration of these water demands.
- The long time lag that can occur between recharge and the eventual appearance of salinity in the landscape also works in reverse. While, in the long term, the outcome for river water quality might be positive, in the short term, saline discharge into streams continues unabated, while surface run-off (i.e. fresh water to dilute the saline inflows) declines. This lag time, as well as the associated uncertainty of 'success', makes it difficult to secure a competitive return on the investment of public or private dollars.
- In many situations it is not possible to accurately identify the location where the recharge is occurring. This is particularly the case for intermediate and regional groundwater systems. Also, recharge may be occurring over vast areas, making vegetative control impractical.

Sheep grazing lucerne.

- Many of the proposed high water use systems (such as agroforestry) are less profitable, and/or more complex, and/or require major up-front investments compared to the annual crops and pastures they potentially replace. Farmers are unlikely to voluntarily adopt such systems.

The result of these issues has been a significant rethinking of the approach to dryland salinity. It is difficult to confidently make either public or private investments that reduce recharge when the cost is high, large areas need to be revegetated, the lag time between the investment and the elimination of salinity may be 100 years, and there is a significant chance of associated negative outcomes.

The case for managing discharge

The appearance of dryland salinity has been observed on farms across southern Australia since the early part of the 20th Century. As early as 1924, the association between clearing native vegetation and the on-set of dryland salinity was reported in the scientific literature.

The National Land & Water Resources Audit (2000)[2] reported on the extent of existing salinity and the inevitability of dryland salinity being an on-going feature of the agricultural landscape. Prior to this there were only sporadic efforts to understand and manage saltland in Australia. The Audit recommended that all State salinity strategies contain explicit plans that included the 'living with salinity' option.

Where does discharge occur?

While it is difficult to estimate the actual area of dryland salinity that will occur in a catchment, it is relatively easy to map where it could occur. Because it is caused by saline groundwater rising towards the soil surface and into the root zone, dryland salinity tends to occur in the lower parts of the landscape. However, groundwater can also form perched watertables where the lateral flow is interrupted by geological features, break of slope or man-made structures such as roads. Salinity often interacts with waterlogging on saltland soils, which can have additional adverse effects on plant growth and survival.

Where the landscape is very flat, such as in much of Western Australia's South West and the Upper South East of South Australia, dryland salinity can affect extensive areas. However, in many other areas, dryland salinity appears as relatively small 'patches' scattered along the lower parts of the local landscape. The result is lots of farms, each with small areas of dryland salinity.

The Australian Bureau of Statistics (ABS) survey of farmers with saltland found that there was about two million hectares of saltland reported by farmers as showing signs of dryland salinity, scattered across nearly 20,000 farms – simplistically an 'average' of 100 ha per farm.[13] However, salinity is not democratic so the impact of salinity on different farms is highly variable. Most farms have relatively small areas affected, but some have very large areas.

At about the same time as the ABS study, a survey of woolgrowers across Australia found that 41% of all farms had areas affected by dryland salinity. While the salinity estimates from the two surveys cannot be directly compared, the woolgrower survey concluded that because of the areas per farm are not normally distributed, a mean value should not be calculated, and that using the median figure was more appropriate – in this case the median, or middle value was about 20 ha.[13]

The unevenness of saltland distribution across farms can be even more apparent in a severely affected State like Western Australia. The Land Monitor database (determined from LandSat imagery) suggests that the median farm in Western Australia is 2.8% salt affected. However, the same dataset shows that for the most severely affected 10% of farms, more than 18% of the farm is salt affected.

Opportunities for productive use

The National Dryland Salinity Program commissioned the first comprehensive assessment of the 'opportunities' that saline land and water resources in the landscape might provide. In 2000, the *Options for the Productive Use of Salinity (OPUS)*[14] project explored in detail a large range of possibilities, including various saltland pastures, saltland forestry, aquaculture, algae/seaweed, date palms and salt/mineral extraction options. The conclusion from the *OPUS* project was that most of the possibilities were very limited. The only realistic possibility was the development of saltland pastures for the existing grazing industries. Since the OPUS project was completed a small number of salt/extraction enterprises have continued and there have been further trials with saline aquaculture. However, the prospects still appear to lean strongly towards saltland agronomy.

The 2007 publication *Prospects for profit and pride from saline land*[15] concluded that the economic prospects from saltland pastures are good, and in some cases excellent. Saltland pastures on medium and high-capability saltland can be both productive and profitable. The extent to which such prospects can be realised by individual farmers will vary according to regional, local and property characteristics, the levels of soil salinity and waterlogging, the plant systems selected and management priorities. Importantly, the report concludes that there are no profitable options for saltland of the lowest capability (i.e. the most salty and/or waterlogged), so the identification of these land classes and their exclusion from saltland revegetation programs is an important part of any investment strategy.

Duty of care, personal pride from improving the visual amenity of the farm, and satisfaction in overcoming a serious challenge are also very significant motivators for landholders. Even with severely degraded land, preventing further deterioration and off-site damage is important.

This saline discharge site occurs low in the landscape and has resulted in an extensive area of scalding.

Difficulties and risks

Saltland sites, especially if waterlogging is an additional feature, are inherently difficult to manage well. Fencing saltland to prevent uncontrolled grazing is always part of best practice because stock preferentially camp on and graze the salty sites, removing much of the vegetation, increasing surface evaporation and thereby further concentrating salts at the soil surface.

If an intervention is primarily to achieve social or environmental goals (which tend to relate to the appearance of the site), the risks are relatively minor once sites are fenced off from grazing.

The major risks associated with grazing saltland are financial. The risk of 'establishment' failure on saltland is much higher than for conventional sites. Seeds of salt-tolerant species (e.g. saltbush) can be quite sensitive to waterlogging and salinity, and conventional sowing equipment is often not well suited to saltland species.

The frequent combination of salinity and waterlogging often means that the opportunity to sow or plant the saltland pasture following opening rains is brief. This is exacerbated when saltland pasture is generally seen as a low priority compared to establishing the farm's main crops and/or pastures.

Where the area of saltland is small, the capital cost of fencing and providing water can mean that an economic return is a very distant prospect.

Depending on the site, the combination of salinity and waterlogging, and the effectiveness of establishment, the production achieved from a saltland pasture may not be sufficient to provide a significant return on the investment. Saltland pastures cost as much (or sometimes more) to establish as conventional pastures, but can have significantly lower productive potential.

In summary, establishing saltland pastures is rarely the next best investment opportunity on a farm from a purely economic perspective. In most cases, farmers are seeking some financial return, combined with social and environmental benefits.

Saltland capability

All soils contain salts of various types. It is not until these salts build up in the soil to the extent that sensitive plants begin to be affected by the salt (most commonly sodium chloride) that land enters our classification of 'saltland'.

Although 'saltland' is clearly affected by salinity, it is often affected by other stresses. Foremost among these is waterlogging, but saltland can also be affected by soil texture, extremes of pH, cemented pans in the soil, etc.

Land is described as 'non-saline' if it has a summer EC_e (electrical conductivity of the saturated soil extract) of less than 2 dS/m. In general terms, as the salinity increases (i.e. as the EC_e value increases) then the growth potential for both salt-sensitive and salt-tolerant plants declines. This happens quickly for salt-sensitive plants, and more slowly for salt-tolerant ones.

However, which plants will actually survive and how much they will grow in a particular salt-affected soil is only partly determined by the actual salinity level in the soil. The other key factors that affect plant growth at a saline site include:

- Waterlogging, which reduces the oxygen available to plant roots, reducing the energy available in the roots to prevent uptake of salts. Some plants can be highly tolerant of soil salinity, but susceptible to waterlogging – old man saltbush is a good example. In general, the combination of salinity and waterlogging or inundation is far more damaging to plants than one or the other stress acting independently.
- Soil texture: it is more difficult for plants to extract water from clay soils than sandy soils. Salt in soils makes it more difficult for plant roots to extract water because of the osmotic attraction between salt and water molecules. It is not surprising then that, with similar soil salinities and depths to the watertable, plants are more severely affected in clay soils than in sandy soils. In Western Australia, a rule of thumb is that in sandy soils saltbush can be established from seed, while in clay soils, nursery-raised seedlings must be used because the conditions are more difficult.

In an attempt to develop and implement a common language for salt-affected land, the CRC Salinity introduced the concept of 'saltland capability'.[77]

'Saltland capability' refers to the specific ability of a salt-affected site to support plant growth year on year. Saltland capability is mostly affected by the levels of salinity and waterlogging on the site.

In general, we can distinguish between three levels of capability:

- Saltland of high capability will have many options for productive systems, the severity of salinity and/or waterlogging will be low to moderate, and the profitability of saltland pastures will be relatively high.
- Saltland of moderate capability will have more limited options for productive systems, the severity of salinity and/or waterlogging will be moderate, and the profitability of saltland pastures will be low.
- Saltland of low capability will generally not be suited to the growth of saltland pastures, the severity of salinity and/or waterlogging will be high to extreme, and the best option for this land will be to fence it off and allow it to revegetate naturally.

If one site is more hostile to plant growth than another, it is defined as having a lower saltland capability, regardless of whether that capability is most severely limited by salinity, or by combinations of salinity, waterlogging and soil texture.

This definition takes account of the fact that while salinity and waterlogging can be highly seasonally variable, the kinds of plants that a site grows year in, year out, are relatively unchanging. For example, a paddock that is growing samphire this year will probably be growing samphire next year – although the salt concentrations in the surface soil and the depth to the watertable may change dramatically with the seasons. Such a site has a low saltland capability and that is what leads it to grow samphire.

The saltland capability concept has been applied to each of the major salinity regions across southern Australia so that the local issues and conditions can be retained, but within a nationally accepted framework. Two examples are presented in the tables below:

- South-west Victoria
- Eastern/Northern Wheatbelt in WA

See the Saltland Genie website[78] for details on:

- Central wheatbelt (WA)
- Woolbelt and west midlands (WA)
- Southern coast (WA)
- Northern Eyre Peninsula, northern York Peninsula and mid-north (SA)
- Southern Eyre Peninsula and Coorong (SA)
- Southern York Peninsula, Kangaroo Island and the Upper South East (SA)
- Adelaide Hills (SA)
- Northern Slopes (NSW)
- Central slopes and plains (NSW)
- Southern slopes (NSW)
- Northern districts (Vic)
- South-west districts (Vic)
- Gippsland (Vic)
- NAP region (Tas)

Saltland capability in south-west Victoria

Table 2.1: The 'saltland capability' concept applied to the saline situations in south-west Victoria.

Saltland Capability	Indicators	Recommended Plant System	Productive Potential
Low	Large areas of bare ground, salt crusting on soil surface. These are often areas of primary salinity adjacent to salt lakes (Class 3)	Fence separately, minimal grazing	Low; pasture growth 4 t/ha, carrying capacity up to 3 DSE/ha mid-spring to late autumn. Sheep gain weight rapidly during spring but slowly during summer and autumn.
	Highly prone to waterlogging and inundation, bare areas up to 1 m^2, variable salinity, salt couch, cotula and buckshorn plantain naturalised (Class 2)	Fence separately to encourage adapted volunteer species; puccinellia and tall wheatgrass can be sown if suitable volunteers are not present	Moderate; pasture growth 7 t/ha, carrying capacity up to 9 DSE/ha from mid-spring to late autumn. Sheep gain weight rapidly during spring but slowly during the dry conditions of summer and autumn.
	Low-moderately saline, moderate waterlogging, ryegrass, and subclover not present (Class 1)	Tall wheatgrass, puccinellia with companion legumes; introduced grasses should not be sown close to waterways or primary saline sites	High; pasture growth 10 t/ha, carrying capacity 20 DSE/ha from mid-spring to late autumn. Sheep gain weight rapidly during spring but slowly during the dry conditions of summer and autumn.
High	Low salinity, low-moderate waterlogging, waterlogging and salinity emerging (Class 0)	Tall fescue, tall wheatgrass and companion legumes	Very high; pasture growth 15 t/ha, carrying capacity 26 DSE/ha from mid-spring to late autumn. Sheep gain weight rapidly during spring but slowly during the dry conditions of summer and autumn.

Saltland capability in WA's Northern and Eastern Wheatbelt

Table 2.2: The 'saltland capability concept applied to the saline situations in the Northern and Eastern Wheatbelt in Western Australia.

Saltland Capability	Indicators	Recommended Plant System	Productive Potential
Low	Scalded, inundated, high salinity, clay soils, samphire, curly ryegrass	Samphire	Low (less than 0.5 t/ha; not suited to grazing)
	Patchy scalding, sea barleygrass, prone to waterlogging, mod-high salinity, samphire on more affected boundary	Dense saltbush	Low-moderate (0.5 to 1.0 t/ha; will maintain sheep if supplemented with good hay)
	Morrel soils, moderately saline, low-moderate waterlogging, sea barleygrass, bluebush	Bluebush	Low-moderate (0.5 to 1.0 t/ha; will maintain sheep if supplemented with good hay)
	Duplex soils, low-moderate salinity and waterlogging	Alleyed saltbush with under-storey	Moderate-high (0.7 to 2.0 t/ha; sheep will gain weight if annual legumes in under-storey)
High	Ryegrass, low-moderate salinity, low waterlogging; subclover and capeweed disappearing, uneconomic for wheat, salinity emerging	Barley, salt-tolerant annual legume pastures	Moderate-high (barley yields up to 2 t/ha; annual legume pastures up to 3 t/ha; sheep will gain weight)

Measuring salinity and waterlogging

IMPACT ON PLANTS

Salinity refers to the presence of dissolved salts in soil and water, and the impact on plants is independent of whether the salinity is natural ('primary' salinity that was present prior to the development of land for agriculture) or human-induced ('secondary' salinity largely caused by land use change).

Salinity affects crops and pastures by effectively reducing the amount of water available to the plant – somewhat ironic, given that salinity often occurs in association with waterlogging. The more salt in the soil, the harder it is for plants to extract water from the soil. There can also be impacts from the toxic effects of some salts, poor soil aeration, or other harmful soil properties such as sodicity.

Some plants are extremely sensitive to salinity, while others are moderately tolerant and yet others highly salt-tolerant. Figure 2.1 gives a broad overview of the relative tolerance of crops and pastures to soil salinity.[79]

Charts such this one should be used only as a general guide, as not all salts are the same and in a paddock situation soil salinity can never be considered in isolation from other factors such as waterlogging and soil type.

Salinity indicators

Indicators are signs or symptoms that suggest salinity *might be* affecting a site. Some of the common indicators include:

- sites may be moist in summer; sheep especially like to overgraze and camp on them during summer, so they become bare and 'scalded';
- often soil colour will change, becoming darker as the site stays wet longer;
- the sites may be especially waterlogged (boggy) in winter – water may even pool on the soil surface;
- patches in cropping paddocks show poor health;
- salt-tolerant plants begin to appear;
- trees and shrubs decline or die; and
- white crusts develop on the soil surface when it dries out.

However, indicators are not always easy to detect and some are similar to indicators of other problems, for example, tree dieback may be caused by non-saline waterlogging, insect attack or fungal diseases. Local knowledge is very useful. If you are unfamiliar with the particular symptoms associated with early stages of land salinisation in your district, it is a good idea to consult someone with local knowledge.

Figure 2.1: Relative tolerance of crops and pastures to soil salinity.

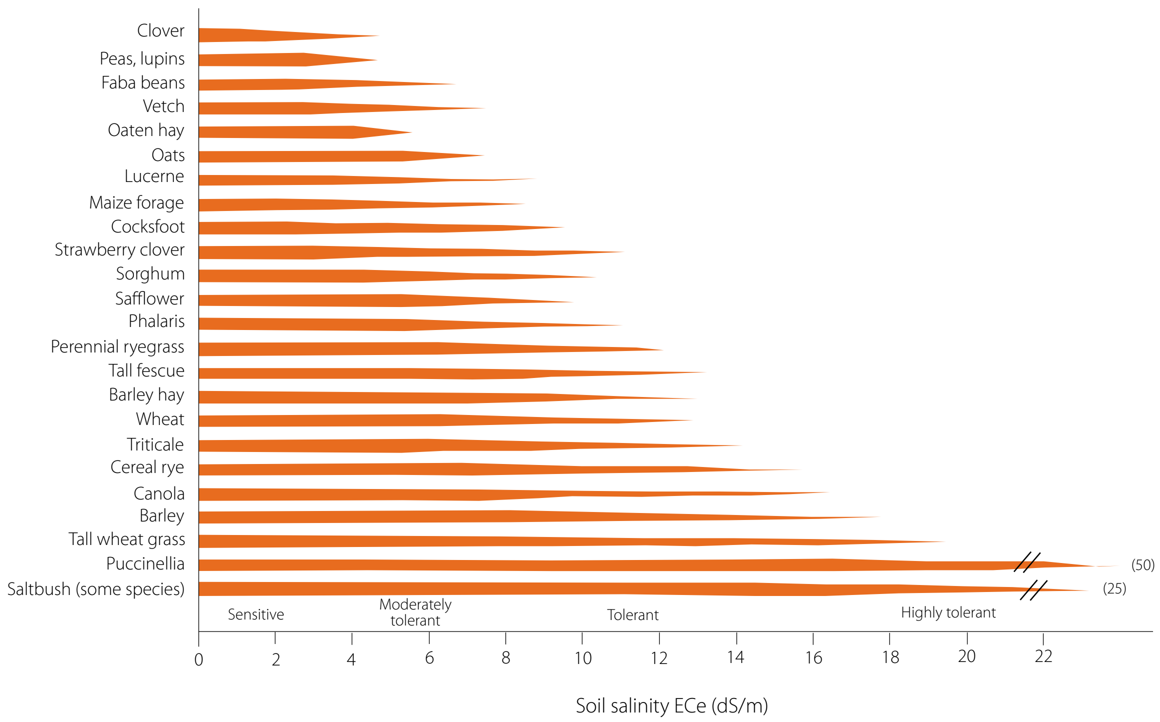


Table 2.3: Indicators for sites with low salinity.

Salinity Classification – Low (subsoil salinity 2 – 4 dS/m EC_e)
Sensitive plants start to be visibly affected on the saltland site, there is reduced vigour of annual legumes and the most salt sensitive (e.g. sub-clover) disappear. The vigour and yield of some grain legumes are affected, but cereals are generally not visibly affected by low salinity levels.

Indicator species for low/moderate waterlogging:	*Indicator species for high levels of waterlogging:*
capeweed, annual ryegrass, barley grass, woolly clover, smooth heliotrope, pigweed, ice plant, windmill grass, prairie grass, burr medic. Sown pasture species such as Italian ryegrass, Rhodes grass, kikuyu, Persian clover, gland clover, balansa clover, lucerne, barrel medic, phalaris, or tall fescue may also be present.	Yorkshire fog, spiny rush, toad rush, beard grass, barley grass, buck's horn plantain, common couch. Sown pasture species such as tall wheatgrass, puccinellia, kikuyu, strawberry clover, Persian clover, gland clover or balansa clover may also be present.

Table 2.4: Indicators for sites with moderate salinity.

Salinity Classification – Moderate (subsoil salinity 4-8 dS/m EC_e)
Most agricultural plants are visibly affected. Annual legumes are struggling to survive or are absent from the site. Plant growth is often patchy. Grain legumes and cereals are strongly affected. Most perennial pasture grasses also show reduced growth and vigour.

Indicator species for low/moderate waterlogging:	*Indicator species for high levels of waterlogging:*
Sea barleygrass, beard grass, black roly poly, woolly clover, ruby saltbush, common couch, Yorkshire fog, smooth heliotrope, pigweed, ice plant, bushy starwort, buck's horn plantain, groundsel bush, rhagodia, orache, wavy-leaf saltbush, small leaf bluebush, ruby saltbush. Sown saltland and pasture species such as river saltbush, old man saltbush, creeping saltbush, golden wreath wattle, Italian ryegrass, annual ryegrass, tall wheatgrass, Rhodes grass, burr medic, phalaris or tall fescue may also be present.	Yorkshire fog, toad rush, spiny rush, Australian saltgrass, beard grass, orache, groundsel bush, river saltbush, marine couch, saltwater couch, common couch. Sown saltland and pasture species such as puccinellia, kikuyu, tall wheatgrass, strawberry clover, Persian clover or gland clover may also be present.

Table 2.5: Indicators for sites with high salinity.

Salinity Classification – High (subsoil salinity 8-16 dS/m EC_e)
Even salt tolerant plants are affected at this level of salinity. Annual legumes are completely absent and even the most salt tolerant cereals (barley and cereal rye) are highly restricted by the conditions. Sea barley grass often dominates these highly saline sites. Bare areas are likely to be present – these may be large if uncontrolled grazing by sheep is allowed. Trees may be dying on and around the site.

Indicator species for low/moderate waterlogging:	*Indicator species for high levels of waterlogging:*
Sea barley grass, small leaf bluebush, buck's horn plantain, ice plant, stonecrop, salt sand spurrey, bushy starwort, beard grass, orache, wavy-leaf saltbush. Sown saltland species such as river saltbush, old man saltbush, golden wreath wattle or tall wheatgrass may also be present.	Water buttons, streaked arrow grass, glasswort, creeping brookweed, curly ryegrass, Australian saltgrass, samphire, marine couch, saltwater couch. Sown saltland species such as puccinellia or distichlis may also be present.

Table 2.6: Indicators for sites with severe salinity.

Salinity Classification – Severe (subsoil salinity 16-32 dS/m EC_e)
Such sites are only suitable for highly salt tolerant plants. There will usually be significant areas of bare ground and it is likely that salt crystals will form on the soil surface over summer. Waterlogging is common, and trees will usually be dead or dying.

Indicator species for low/moderate waterlogging:	*Indicator species for high levels of waterlogging:*
Samphire, curly ryegrass, marine and saltwater couch, ice plant, streaked arrow grass, salt sand spurrey, sea barley grass, old man saltbush, bare ground.	Samphire, glasswort, curly ryegrass, marine couch, saltwater couch, curly ryegrass, streaked arrow grass, water buttons, creeping brookweed, puccinellia, distichlis, bare ground.

Table 2.7: Indicators for sites with extreme salinity.

Salinity Classification – Extreme (subsoil salinity 16-32 dS/m EC_e)
Only the most salt and waterlogging tolerant species can survive at these salinity levels and saltland pastures are not an option.

Indicator species for low/moderate waterlogging:	*Indicator species for high levels of waterlogging:*
Mostly bare ground and extensive salt crystallisation at the soil surface.	Samphire, glasswort, water buttons, bare ground

Table 2.8: Australian classification system for classification of soil salinity.

Term	EC_e range (dS/m)	$EC_{1:5}$ range			Typical plants affected
		For sands (dS/m)	For loams (dS/m)	For clays (dS/m)	
Non-saline	0–2	0–0.14	0–0.18	0–0.25	–
Low salinity	2–4	0.15–0.28	0.19–0.36	0.26–0.50	Beans
Moderate salinity	4–8	0.28–0.57	0.37–0.72	0.51–1.00	Barley
High salinity	8–16	0.58–1.14	0.73–1.45	1.01–2.00	River saltbush
Severe salinity	16–32	1.15–2.28	1.46–2.90	2.01–4.00	Puccinellia
Extreme salinity	> 32	>2.29	>2.91	>4.01	Samphire

The actual salinity measurements associated with different classifications of soil salinity are presented in Table 2.8, but the indicators in Tables 2.3 to 2.7 can provide some 'guidance' as to the severity of salinity and waterlogging.

Measuring salinity of soil samples

Measuring soil salinity in the plant root zone can be important in confirming dryland salinity and in the selection of appropriate salt-tolerant species so as to avoid expensive mistakes. There are many publications that can assist in taking and interpreting salinity measures.[80]

Salt increases the ability of water to conduct electricity – the more salt there is in a solution, the easier it is for electric current to flow. Therefore, measuring electrical conductivity (EC) is an indirect measure of the salt content, often expressed as desiSiemens per metre (dS/m).

There are two ways to measure soil salinity:

- EC_e is the electrical conductivity of a saturated soil paste extract and can only be measured in a laboratory. The soil saturation extract is created by adding water to a dry soil until it becomes just saturated. This water is separated from the soil, and the salinity of the water is measured. EC_e values are the standard way to display plant soil salinity tolerance data, but EC_e cannot be measured by farmers in the paddock, and is more expensive.
- $EC_{1:5}$ (EC 1 to 5) is the electrical conductivity of a 1:5 soil/ water mix. $EC_{1:5}$ values provide a cheap and easy way to estimate EC_e. It requires access to a hand-held EC meter and a vessel in which to mix 1 part dry soil and 5 parts rainwater by volume. The mixture is shaken vigorously and after allowing time for settling, the electrical conductivity of the clearer fluid at the top can be measured.

Researchers prefer to use EC_e as the measure of soil salinity because it is directly related to the salinity of the soil solution, i.e. the salinity that plants growing in the soil actually experience. In saturated (waterlogged) soil, roots experience a salinity equivalent to the EC_e. As the soil dries, however, the plants experience increasing salinity in the soil solution until, at wilting point, the salinity of the soil solution will be approximately four times the measured EC_e.

Fortunately, there are rules of thumb than can be used to convert $EC_{1:5}$ readings to EC_e readings, but they depend on soil texture, as shown with the following conversions:

- for sands multiply the $EC_{1:5}$ value by 15;
- for loams multiply the $EC_{1:5}$ value by 9.5;
- for clays multiply the $EC_{1:5}$ value by 6.5; or
- use values in between for 'intermediate' soil types.

Table 2.8 shows the Australian classification for soil salinity based on EC_e values, with conversions for $EC_{1:5}$ values in soils of different textures.

Many people relate to salinity through their experience with seawater. A useful rule of thumb to remember is that salinities can be converted to their equivalent as a percentage of seawater knowing that the electrical conductivity of seawater is about 55 dS/m.

However, salinity is often measured by researchers using a wider range of units (e.g. moles per litre, milligrams per litre, megaPascales, etc). Also, many older farmers still refer to salinities in terms of 'grains per gallon'. Values in any unit can be converted into their approximate equivalent using the conversion factors in Table 2.9.

Table 2.9: Unit conversions for soil and groundwater salinity.

Soil and Water Salinity Units		dS/m	mS/cm	µS/cm	mg/L ppm	gr/gal	mol/m^3	mmol/L
		conversion factors						
decisiemens per metre	dS/m		1	1000	670	40	12	12
millisiemens per centimetre	mS/cm	1		1000	670	40	12	12
microsiemens per centimetre	µS/cm	0.001	0.001		0.67	0.04	0.01	0.01
milligrams per litre; parts per million	mg/L ppm	0.0015	0.0015	1.5		0.06	0.02	0.02
grains per gallon	gr/gal	0.02	0.02	20	14		0.3	0.3
moles per cubic metre	mol/m^3	0.085	0.085	85	55	3		1
millimoles per litre	mmol/L	0.085	0.085	85	55	3	1	

Conversion: select the unit to be converted down the left hand column and then move across to the column containing the desired unit and multiply by the corresponding factor.

Example: to convert dS/m to mg/L, multiply by 670 (i.e. 7 dS/m is equivalent to 4,690 mg/L)

Measuring salinity in situ

The salinity of soil samples is determined by measuring the electrical conductivity of a soil-water solution because conductivity increases with salinity. The same principle can be used in the field with 'electromagnetic induction' used to estimate the apparent electrical conductivity of the bulk of the soil. The tools that measure this electromagnetic induction are called 'EM' meters – either EM38 (for shallow soil measurement – less than a metre) or EM31 (for measuring deeper in the soil – up to 6 m). The EM38 is used in the explanation below because it 'measures' salinity in the root zone and is therefore a more appropriate tool for matching potential plants with saline sites.

The soil depth over which the EM38 will read depends on the orientation of the instrument – it has both vertical and horizontal orientations. In the horizontal position, 50% of the measurement is taken from the upper 0.4 m of the soil profile; in the vertical position, 50% of the measurement is taken from the upper 0.85 m of the soil profile. If one wanted to locate shallow-rooted plant species in a saline landscape, then the EM38 should be used in the horizontal orientation, but if one wanted to locate deeper-rooted plants in the landscape then the EM38 should be used in the vertical setting. The EM maps (Figure 2.2) for the SGSL site near Hamilton (Victoria) suggest that for some areas (for example in the lower left quarter of the maps), the salinity was highest in the deeper soil, while in other areas (mostly on the upper half of the maps), the salinity was higher in the shallow soil.

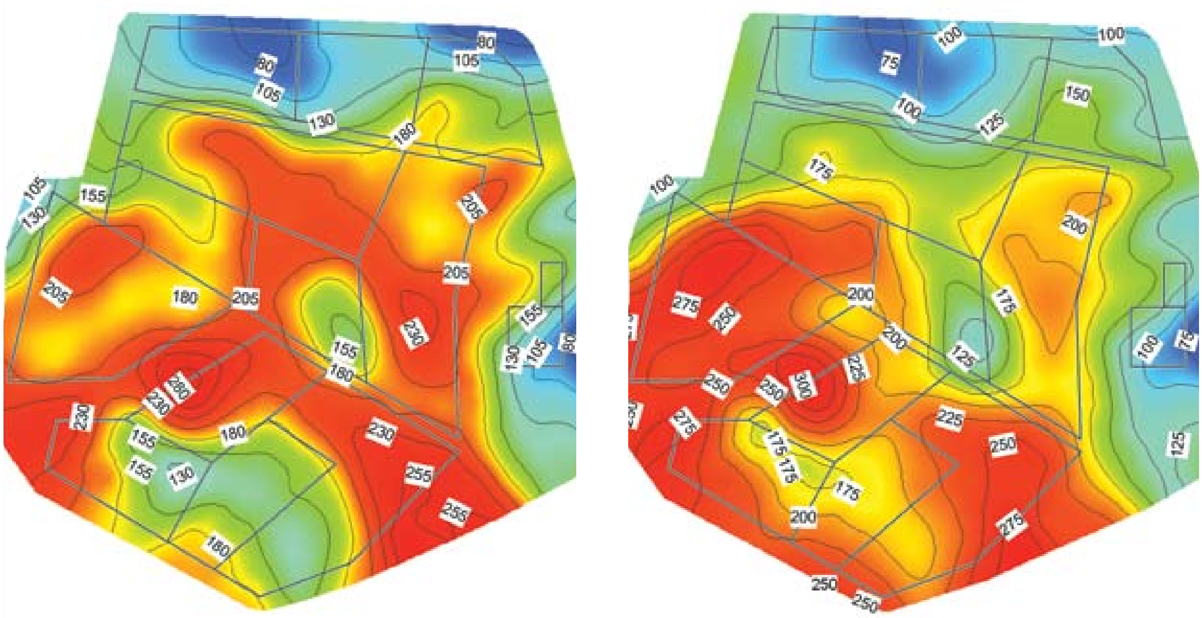
Unfortunately, EM38 readings are not just affected by soil salinity; they are also affected by: (a) soil moisture – other things being equal dry soils will have lower readings than moist soils, and (b) soil texture – other things being equal clays have higher readings than loams and sands. In other words, there will not be strong universal relationships between EM38 readings and plant growth and survival. However, the EM38 can be used as a mapping tool to indicate general areas of higher conductivity compared with general areas of lower conductivity, and this can be a valuable tool in helping farmers identify differences in saltland capability at the paddock scale and develop paddock-scale plans.

Because the EM38 measures an 'apparent' electrical conductivity in the soil, these readings are often abbreviated as ECa readings.

Variability of soil salinity measurements

A big problem with surface soil salinity is that it can vary greatly through the year. Figure 2.3 shows EC_e data from the SGSL site in Western Victoria for the surface 10 cm of soil for three areas from the same site as shown in the EM38 maps in Figure 2.2. As a general rule, salinity peaks in late summer or autumn when much of the soil moisture has evaporated, concentrating the salt in the soil surface. In Figure 2.3, the concentration effect over

Figures 2.2a and 2.2b: EM38 'maps' of the SGSL site near Hamilton – the stronger the red colour, the higher the salinity reading. The map on the left shows readings taken in the 'horizontal' or shallow mode; the one on the right shows readings taken in the 'vertical' or deeper mode.



summer was strongest at the locations within the site that had the highest overall salinity.

These data clearly show what a poor diagnostic the measurement of shallow soil salinity can be – the values are highly variable in time and do not provide a consistent view of the 'inherent' capability of the site. For example, depending on the date of sampling, the soils of the red line could have been classified as being anything between highly saline (12 dS/m) to extremely saline (48 dS/m), the soils of the blue line could have been classified as being anything from moderately saline (6 dS/m) to severely saline (26 dS/m), and the soils of the green line could have been classified as being anything from non-saline (2 dS/m) to highly saline (9 dS/m).

Another example of the extreme variation in surface soil salinity is presented in Figure 2.4, from data collected by Stan Smith in 1956 on a completely bare piece of saltland near Quairading in Western Australia.

These data illustrate an important point – surface soil salinity measurements are extremely variable and can give quite misleading information about the capability of saltland sites. As a result, it is often better to base assessments of saltland capability on the salinity of the subsoil (depth 25–50 cm) and recommend this for others. Because these values don't change very much seasonally (see Figure 2.4), we can take the readings at nearly any time of year to predict a site's capacity.

The challenge associated with the fact that salinity also varies greatly across most saline sites is more difficult. The spatial variation at the SGSL site in western Victoria (shown in Figures 2.2) is quite typical. Taking an 'average' over such variable sites gives little indication of what might profitably be sown in a location. If a site consists of a mixture of bare and grassy areas, we suggest that separate samples be taken of subsoil salinity beneath grasses and beneath the bare areas. This will give a good indication of the extent of variation; the recommended planting may need to consist of a shotgun mixture of species to accommodate this variation.

Measuring waterlogging

Most dryland salinity is caused by the presence of shallow watertables in the landscape. Watertables typically rise and fall seasonally in response to rainfall, internal drainage and evapotranspiration. If watertables become shallower than about 30–40 cm, the soils may become 'waterlogged'.

Waterlogging causes soils to become devoid of oxygen, often within a few days. In addition, waterlogging causes an accumulation in the soil of carbon dioxide, a range of organic compounds such as ethanol and organic acids, and the plant hormone ethylene. With prolonged waterlogging to the soil surface, anaerobic bacteria in the soil can change soil nitrogen, manganese, iron and sulphur to forms that are either lost from the soil (soil nitrogen is transformed into atmospheric nitrogen) or that are toxic to plants.

Although oxygen deficiencies are the major cause of waterlogging damage to plants, such deficiencies are nearly impossible to measure on a paddock-scale. We therefore classify waterlogging on the basis of the depth to watertable in winter as shown in Table 2.10 (over page).

Figure 2.3: Soil salinity (ECe) variation over time at the SGSL site in Western Victoria. The red line is the average across parts of the site that have high salinity, blue from sites that have moderate salinity and greens from sites that have low salinity.

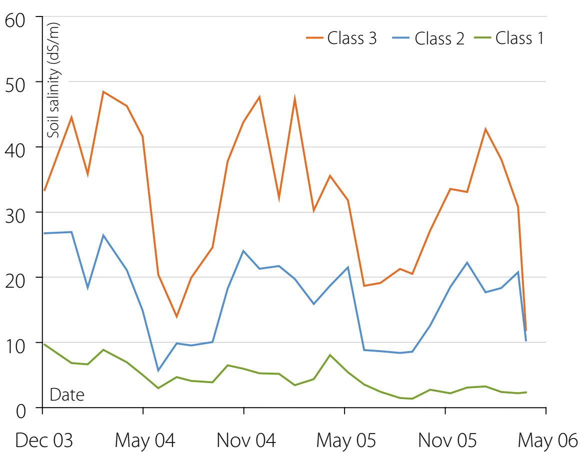


Figure 2.4: Seasonal changes in soil salinity down an uncultivated soil profile near Quairading WA (after Smith, 1962).

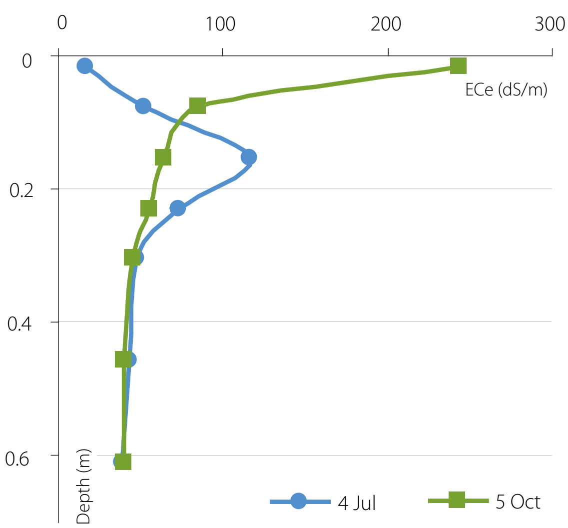


Table 2.10: Classification of soil waterlogging status using depth to the watertable in winter.		
Severity of waterlogging	Average depth to watertable (m) in winter	Suitable plants
Non-waterlogged	Deeper than 0.5	Old man saltbush, small leaf bluebush
Low waterlogging	0.3 – 0.5	River saltbush, Rhodes grass, kikuyu
Moderate waterlogging	0.1–0.3	Tall wheatgrass
High waterlogging	0 – 0.1	Puccinellia, saltwater couch, samphire

Managing surface water

Waterlogging in soils is simply an excess of water held above field capacity – water that cannot drain away because of a high watertable or an impermeable layer in the soil. Plant growth can begin to be affected by waterlogging when average watertables are less than about 0.5 m deep in winter.

By filling the soil pores with water instead of air, waterlogging reduces the oxygen supply to plant roots. This lack of oxygen induces an energy deficiency which reduces the ability of roots to perform many of their normal functions. Most importantly in the context of salinity, roots require energy to prevent salt from entering them, so waterlogging reduces the plants' ability to prevent salt uptake. In other words, while salinity and waterlogging are both 'detrimental' to plant health, in combination they are considerably more difficult for plants to tolerate.

Waterlogging is a common companion for dryland salinity because, by definition, many saline sites have shallow watertables and are located in the lowest positions in the landscape. Reducing waterlogging is often required for the successful establishment and persistence of saltland pastures, and to reduce the soil pugging and compaction associated with grazing. Therefore, it is not surprising that drainage is often one of the things that needs to be considered when attempting to improve the productive capability of saltland.

There are two forms of drainage to consider:

- Drains that either divert surface water from flowing on to saline areas, or that remove surface water from saline sites. These are often collectively called 'shallow' drains.
- Drains that intercept the watertable and drain water from it, thereby lowering the watertable and reducing both salinity and waterlogging. These are often collectively called 'deep' drains.

Shallow drains (includes raised beds)

Shallow drains of various forms reduce the effect of inundation and surface waterlogging by either diverting surface water that would otherwise run on to the salty site, or by collecting surface water from the site and enabling it to run off. Raised beds, which some farmers have found very beneficial,[81] also fit into this form of drainage.

Either way, the effect is to prevent surface water from ponding on the site, and/or from infiltrating into the saline soil, further raising the watertable. If the watertable rises, then more salts are likely to concentrate at the soil surface in spring and summer as water evaporates from the site.

Shallow drains are most likely to be effective where:

- topography is relatively flat and soils are impermeable (e.g. clays) or highly variable;
- surface water can be diverted without large costs; and
- natural drainage lines are ill-defined or discontinuous.

Problems with shallow/surface drains can include:

- if the drainage water is saline, then disposal to streams (or neighbouring properties) can be problematic, although surface water is never as saline as subsurface drainage and in most jurisdictions surface water is not regarded as 'drainage' water;
- concentrating surface flows can initiate soil erosion.

Raised beds are a specific form of drainage that require land to be engineered in such a way as to allow the seed-bed to be elevated and drainage to occur from close-spaced gutters. Beds are typically 2-3 m wide and may be up to 1,000 m long in ideal locations. Though well regarded in some areas of Australia for cereal cropping, research in SGSL did not indicate that raised beds were a viable proposition for saltland pastures because the added pasture growth usually did not justify the added cost.

Deep drains

Deep drains can intercept a rising watertable and control groundwater levels so as to prevent rising watertables from causing salinity. Alternatively, deep drains can be used to lower already high watertables so as to bring saltland back into production. Deep drains can also be configured to remove surface water, thus reducing inundation and waterlogging. Typically, deep drains are dug to a depth of >1.5 m and are often controversial because of the difficulties associated with disposal of the drainage water which can have some very 'hostile' properties.[82]

The effectiveness of deep drains depends on:

- their location in the landscape, being most effective on the lower parts of the landscape such as valley floors and coastal plains, where the slope is generally less than 0.5%;
- drains being located in permeable soils (so the impact of the drain extends a reasonable distance from the drain itself) that are structurally stable (so that the drains do not collapse); and
- a safe and legal disposal option for the drained water.

Drainage water may be highly saline and/or acidic and so may significantly affect neighbours, waterways and the environment in general. It is not surprising therefore that there are many rules and regulations regarding deep drains though some farmers have had good success with deep drainage.[82]

Alternatives to deep drains include pumps and siphons that bring water from the watertable to the surface – all face the same problems of water disposal and legal restrictions as deep drains.

Sowing saltbush on raised beds. Photo: Ardjen Ryder

Legal considerations

It is not possible in a general publication such as this to outline all the State and regional rules and restrictions relating to deep and shallow drains.

The key point is that no drainage operation should be attempted without first checking the legal requirements because they vary so much from place to place. In some areas (e.g. the Upper South East of SA) drains have been installed in an integrated government program under licence issued by the regional drainage board. In other areas, it is impossible to get permission for drainage works. For example, in some catchments in Victoria, you can only drain a paddock area as long as the drainage water is directed into a holding dam on your own property. In addition, you are not allowed to change flow direction, e.g. if the natural water course is running north/south you cannot change it to flow east/west.

Even where installing deep drains is legal, anyone installing a deep drain may be liable under common law for any damage caused to neighbours by the construction or the operation of the drain.

Check the local rules and regulations before contemplating any (shallow or deep) drainage option for saline land!

The Million Hectares project (funded by the Grains Research & Development Corporation) compiled a very comprehensive overview of drainage options.[83]

Aerial photo showing severity and variability in saltland.

Saltland Solution 1

Fence and exclude from grazing

IN A NUTSHELL

In this package of solutions for saline land, there are two that do not involve grazing:

Solution 1 is recommended for sites that are too saline, waterlogged and/or inundated for other solutions to succeed.

Solution 11 (Revegetation with non-grazing species) is recommended for a much wider suite of saline sites where grazing may be a suitable land use, but other considerations lead to a rehabilitation plan with trees or other non-grazing species as a major component of the revegetation mix. Occasional grazing may be part of this solution, but only at times and at grazing pressures that do not threaten the other benefits being sought (e.g. erosion control, timber production or simply visual amenity).

The sites most likely to suit fencing and exclusion from grazing (highly salty and waterlogged) are suited to the growth of samphire (*Halosarcia* species of which there are several that all go by the common name 'samphire') though other highly waterlogging- and salt-tolerant plants may be present (e.g. curly ryegrass and cotula). Revegetation of this class of land is gradual and episodic, and can occur naturally if grazing is excluded, especially if site preparation like disc pitting is used to provide germination niches. Samphire is not suited to grazing as the salt concentrations in the forage can reach concentrations of 40% and there are likely to be other, anti-nutritional factors.

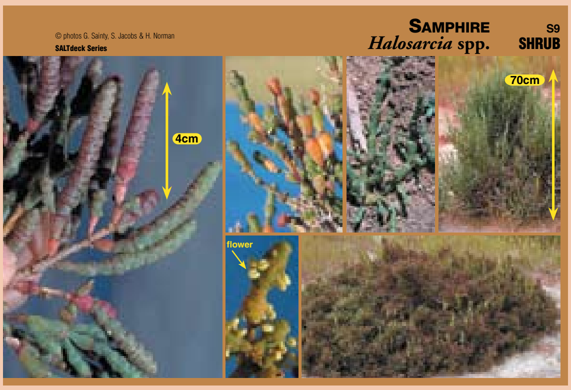
The objective behind this Saltland Solution may be a combination of revegetation to decrease soil erosion, mitigate the severity of flash flooding and to increase amenity values. These sites have no current commercial value, either before or after this Saltland Solution is put in place. Future commercial value is also unlikely, although carbon fixation/sequestration and production of glycine betaine (samphire is high in this) are potential industries for the future.

Within sites that are fenced and have grazing excluded to allow samphire to prosper, other species may colonise, including stands of trees on any sandy rises especially *Casuarina obesa*.

IDENTIFYING SAMPHIRE

Samphire is the common name for a wide ranging group of succulent shrubs, represented in Australia by six genera within the family *Chenopodiaceae*. The *Chenopodiaceae* family also includes the saltbushes (*Atriplex* species) and the *Rhagodia* species that are common saltland plants, though none are as salt- and waterlogging-tolerant as the samphires.

Samphire is a perennial shrub that may have a spreading or erect habit and can be up to one metre high. Branches consist of succulent, compressed stem segments that are hairless, jointed and range from green to reddish-purple. The flowers and seeds are hidden between the fleshy segments and the seeds may be black or brown, smooth or rough depending on the species. Seeds mature in summer but the seed heads may not dry off till autumn.



Samphire Halosarcia spp.

See the SALTdeck identification cards under the resources section of the Saltland Genie website for further information and other common saltland indicator species.

MOST LIKELY SITUATIONS

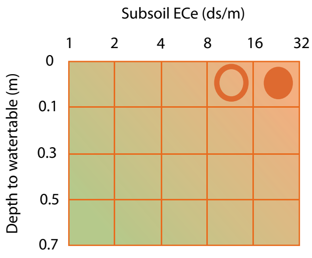
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and are likely to thrive. For samphire (the predominant species associated with this Saltland Solution), these factors are summarised below.

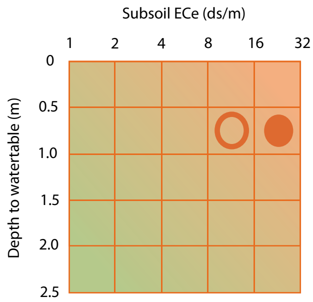
1 – MOST LIKELY SITUATIONS FOR SAMPHIRE

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER



SUMMER



DRIVERS OF PLANT ZONATION

- Shallow-rooted halophyte
- Tolerates high waterlogging, even inundation in winter
- Growth depends on groundwater accessible to roots
- Germinates after flooding
- Rainfall variable

Key to symbols

● *This is the zone most preferred by samphire and where this Saltland Solution is highly recommended.*

○ *Samphire will most likely survive in this zone, but its growth will be poor and uncompetitive with other plant options.*

SOIL AND CLIMATIC REQUIREMENTS

In Australia, samphires are most commonly associated with saline environments. Samphire habitats traditionally included salt lakes and pans, salt marshes and coastal flats, but have now expanded into areas of secondary salinisation, when salinity and waterlogging associated with rising watertables becomes an issue.

Waterlogging/inundation. Samphires can grow in soils that are more or less permanently waterlogged, and some species can withstand up to six months' partial inundation.

Salinity. Samphires are highly salt-tolerant once established. Specimens growing on salt flats near Kalgoorlie in WA have been able to withstand extreme salinity, with measured EC_e values of 70-100 dS/m at depths of 10-20 cm over summer. At Wubin in WA, samphire growing in the SGSL (Sustainable Grazing on Saline Land) experiments had EC_e values of ~40 dS/m at 0-25 cm depth in spring.

Samphire is a typical halophyte. In solution cultures its pattern of growth is lower when salinity is low, increasing to an optimum with an EC in the solution of ~20 dS/m, and then growth gradually declines as concentrations reach 80 dS/m.

Climate. Samphires are endemic across southern Australia and therefore are well adapted to the temperature and rainfall conditions in almost all areas where dryland salinity occurs in the southern States. Germination appears to be temperature responsive: of a range of temperatures tested, optimal germination occurred with a day/night regime of 5–35°C.

Matching plants to a saline site. The degree of salinity and waterlogging tolerance in samphire differs between the various species. The species commonly found on salt flats in WA (*H. pergranulata pergranulata*) will withstand months of waterlogging and weeks of inundation and total submergence. However, there are samphire species that grow on well drained banks around saltland (e.g. *H. indica*) and these plants are almost certainly likely to be more sensitive to inundation. A study of samphire zonation in WA found that the different species selected positions in the landscape primarily in response to soil moisture and salt load. Soil pH also played a small role.

THE BENEFITS

Improvement in visual amenity is a strong driving force behind many farmers' move to revegetate saline land. The most severely affected saltland will often be bare salt scalds if the site is not protected from grazing. Under suitable conditions (extreme salinity and waterlogging), samphire will colonise the site and provide groundcover which can be a significant improvement to the visual affront associated with saline scalds. Samphire might be best described as 'better than nothing', and on these sites, there are no practical or commercial alternatives.

With careful landscape design it may be possible to fence out areas suited to samphire at no additional cost. For example, areas suited to saltbush will generally occur higher in the landscape than areas suited to samphire. If a belt of saltbush was established higher in the landscape and fenced off then the samphire zone in the lower part of the landscape could automatically be protected.

A stand of samphires will stabilise sites to some extent, making them less susceptible to water erosion. Samphire also catches sand from wind erosion and will build mounds of sand around their bases in susceptible areas. They may also provide some benefits by slowing surface water flows so as to decrease the severity of flash flooding but this has not been investigated.

Research on the biodiversity value of saline sites that have been fenced and excluded from grazing to allow samphire to colonise has not been done but it can be surmised that a samphire-based ecosystem would provide significantly better environmental outcomes than a bare, untreated saline scald. Most Australian samphire species are endemic (not found in other countries) and therefore have a biodiversity value in their own right. It is also likely that other salt-tolerant plants will co-exist with the samphire and provide a contribution to both plant and animal biodiversity. In WA, interconnected samphire areas occur across the lines of ancient drainage. These systems act as wildlife refuges for kangaroos and probably for a range of other native animals.

Although samphire areas are generally highly saline and waterlogged, such areas are rarely uniform in shape and fencing them off will inevitably include some less severely affected land. These islands of better ground could be suited to the growth of salt-tolerant trees like *Casuarina obesa*. Like samphire, this tree will also spread naturally if seed is present and the plants are protected from grazing.

Though many samphire species are very common, *Halosarcia flabelliformis* (bead glasswort), a small shrub found on the margins of some salt lakes in Victoria and South Australia is nationally listed as a vulnerable species. It is threatened by excessive flooding, extraction of salt and gypsum deposits, and from grazing by domestic stock and rabbits. Protection of threatened or vulnerable species can make a significant contribution to biodiversity.

It is unlikely (though it has not been researched) that samphire encourages any of the remediation services (i.e. increased water use, watertable drawdown, reduced salt accumulation in the surface soil) that are sometimes associated with other saltland alternatives. It must be kept in mind that sites selected to fence and exclude from grazing have been selected specifically because the salinity and waterlogging are so severe as to exclude other options.

HOW THE $$$s STACK UP

Put simply, they don't.

The fence and exclude from grazing produces no dollars. There has been some discussion about the potential for samphire sites to become a commercial source of glycinebetaine because the plants are high in this compound. However, it is unlikely an industry will be developed in the next decade, so no financial outcomes should be factored into any planning for this saltland solution.

Fencing off an area of severely salinised/waterlogged land and excluding grazing is a 'last resort' management option on a commercial farm. Any sort of economical assessment is meaningless as these severely salinised sites are beyond agricultural production and are fenced off to achieve entirely non-financial outcomes.

For a farmer to be interested in implementing this Saltland Solution, there must be motivation other than production or profit (unless the fencing is carried out for some other purpose). Farmer surveys suggest that visual amenity (improving the appearance of a highly degraded area of the farm, particularly if that area is visible from the house or the road) is a major driver. In addition, farmers often establish saltland pastures with the hope that such pastures can reduce or slow the spread of dryland salinity, but it is unlikely that the sort of severely salinised/ waterlogged land suited to fencing and exclusion from grazing would provide any such benefits.

The mix of benefits being sought will vary significantly from farmer to farmer and therefore each situation has to be assessed on the cost of implementation and the value of the non-financial benefits to the individual farmer.

Minimising the cost of implementation:

- Larger areas are cheaper per hectare to fence. If a saline area is expanding, fencing off a larger area will reduce the cost per hectare and possibly reduce the need to replace the fence in the future.
- Fences have two sides. While there is no potential for commercial gain from the highly saline area, the fencing operation may be used to increase subdivision and therefore grazing management options in adjacent areas. Such fencing might be to allow saltland pasture to be developed on the less saline, less-waterlogged land, or could become part of a laneway system on the farm that can simplify stock movement.
- Community co-investment may be an option. Some Natural Resource Management Councils and Catchment Management Authorities are providing fencing subsidies to assist farmers fence off vulnerable land classes and to increase environmental outcomes. In some cases, these community grants can be used to fence off, establish and protect samphire areas.

In some samphire areas puccinellia may be an option for productive land use. The clearance of samphire is generally restricted where it is considered historical. In South Australia dispensation from clearance regulations can be obtained where it can be demonstrated that the samphire is an invasive species on previously cleared farming land.

HOW RELIABLE IS THE INFORMATION?

There has been very little systematic research into the use of samphire as a land management option, largely because there is no chance of any financial return from investing in samphire on-farm. Consequently, the reliability of the information included in this saltland solution will be considerably less than for well-researched options such as saltbush or salt-tolerant grasses.

When a saline site is protected from grazing, samphire will inevitably occupy the most severely affected saltland, given sufficient time. Samphires generally form the first community around the fringes of severely waterlogged salt scalds and saline lakes.

The dynamics of samphire recruitment are poorly understood, though paradoxically samphire seedlings survive best at low salinities. This is probably why natural samphire establishment appears to be episodic, occurring after floods. Seeds are carried in flood water will germinate after the floods recede on soils that have been substantially leached of salt. Given the importance of flooding, samphire recruitment is likely to be highly variable between sites and years.

ESTABLISHMENT AND MANAGEMENT

ESTABLISHMENT

For farmers wanting to assist the establishment of samphire on their suitable saline land, the recommended method is to fence off the area and let nature take its course.

An alternative is to identify local sites with similar levels of waterlogging and salinity and collect seed from there. This involves harvesting the shoots or whole plants by hand or with a forage harvester, and spreading the harvested material on the ground. Tickling the soil surface with a scarifier can also help create seed niches. As different species can tolerate different conditions, this seed should be sourced from local sites with similar salinity/waterlogging profiles for best results.

Under controlled conditions, seed germination is affected by soil salinity, temperatures and seed scarification. In practical terms, samphires will germinate in spring after soils have been leached by rainfall and/or floodwaters. Therefore, the best time to collect and spread the appropriate samphire species across a site is in autumn after flowering and seed set.

Once some samphire has been established on a site, the stands may be thickened up by cultivating bare areas to encourage soil leaching and create niches in which seeds can lodge.

There is no need to worry about weed control on sites suited to this saltland solution. With the levels of salinity and waterlogging that will be present, weeds have little chance of establishing.

Samphire area fenced from grazing.

MANAGEMENT

Fencing off highly saline areas and excluding them from grazing is essentially a decision not to actively manage that part of the farm, other than to control weeds and vermin.

There are some management considerations associated with assisting the site to become colonised with samphire if it is not already present on the site, as outlined in this chapter.

Areas of the farm that have been converted to conservation rather than production still require some oversight to ensure they do not represent a fire risk, a haven for weeds and feral pests, or erosion sites. Many of these risks are negligible for the core area that will by highly saline and waterlogged, but areas are rarely uniform in shape and fencing them off will inevitably include some less saline, or even non-saline land that may create a haven for weeds or vertebrate pests.

Samphire-dominated sites are not recommended for grazing as it can affect plant survival and seed set, and the high salt concentrations in the forage will have adverse effects on the grazing animals.

SUPPORTING RESOURCES

Datson, B. (2005). Understanding Species Zonation of Samphires (Salicornieae) in the Goldfields of Western Australia. www.actis.com.au/understanding_species_zonation_of_western_australian_samphires.pdf.

English, J.P. (2004). *Ecophysiology of salt- and waterlogging-tolerance in selected species of Halosarcia*. PhD thesis. School of Plant Biology, University of Western Australia, 331 pp. Study of three Halosarcia species from the Hannan's Lake area near Kalgoorlie.

Malcolm, C.V. (1964). Effect of salt, temperature and seed scarification on germination of two varieties of *Arthrocnemum halocnemoides*. *Journal of the Royal Society of Western Australia*, **47**, 71–74.

Pedersen O., Vos H. and Colmer T.D. (2006). Oxygen dynamics during submergence in the halophytic stem succulent *Halosarcia pergranulata*. *Plant, Cell and Environment* **29,** 1388–1399.

Rich, S.M, Ludwig, M. and Colmer, T.D. (2008). Photosynthesis in aquatic adventitious roots of the halophytic stem-succulent *Tecticornia pergranulata* (formerly *Halosarcia pergranulata*). *Plant Cell and Environment* **31**, 1007-1016.

Short, D.C. and Colmer, T.D. (1999). Salt tolerance in the halophyte *Halosarcia pergranulata* subsp. *pergranulata*. *Annals of Botany*, **83**, 207–213.

Stirzaker, R., Vertessy, A. and Sarre, A. (2002). *Trees, water and salt – an Australian guide to using trees for healthy catchments and productive farms* provides a comprehensive guide for those wishing to replant trees in response to dryland salinity. It can be ordered from http://extranet.rirdc.gov.au/eshop/

The *National Dryland Salinity Program* (NDSP 1993–2003) was the first national attempt to better understand the causes, impacts, costs and management options for preventing and/or overcoming dryland salinity. The final year of the program was dedicated to harvesting the knowledge and making it available to the diverse range of stakeholders through the *Managing Dryland Salinity in Australia* resource kit. http://www.ndsp.gov.au/. An update was published by Land & Water Australia in 2006. [http://www.lwa.gov.au/].

Saltland Solution 2

Fence and volunteer pasture

IN A NUTSHELL

The Sustainable Grazing on Saline Land (SGSL) initiative established 120 farm sites (as well as five core research sites) on saltland across WA, SA, Victoria, Tasmania and NSW. All the farm sites were required to have the 'treatment' the farmer group wished to test as well as a 'control'. Similarly, many of the research sites had control areas. These control areas were fenced off and grazed conservatively. In most cases, 'pasture production' from the control plots was surprising – simply fencing-off the saline sites from the rest of the paddock, and grazing them conservatively, resulted in significant improvements in groundcover and productivity. Better still, the costs associated with the control plots were minimal (fencing and water supply only) and the risk of failure reduced to almost zero. For highly saline/waterlogged sites, this approach will often result in the establishment of samphire, which has no commercial value as outlined in Saltland Solution 1 – Fence and exclude from grazing.

Recently, the research data from the SGSL program was re-examined to provide more information on the value of the fence and volunteer option. That analysis concluded that total farm profits are higher from improved pasture than from the fence and volunteer pasture option, but the fence and volunteer pastures resulted in a higher marginal return on investment than that achieved for the improved pastures. In addition, as the costs associated with the fence and volunteer pasture option are significantly lower, the farmer is exposed to less financial risk. The only significant risk is that the pasture that 'establishes' once the fence goes up may not be the type of pasture the farmer wants. This risk is mitigated by the fact that fencing and volunteer pasture does not preclude a later decision to sow improved saltland species.

As outlined in this Saltland Solution, the role of fencing and volunteer pastures has been underplayed when, in fact, it offers an exciting option in many situations because of its low cost, high marginal return, low risk and ease of implementation.

One of the great problems with patches of saltland within a larger paddock is overgrazing. Sheep in particular are highly attracted to saltland partly because it tends to be cool (i.e. damp) to lie on, and also because they are attracted to the salt itself and the salty plants growing there. Many saline areas are completely bare, not because they are so saline as to prevent plants establishing, but simply because the livestock have eaten any plants down to the ground. Thus fencing has been a key management action since the early days of saltland research.

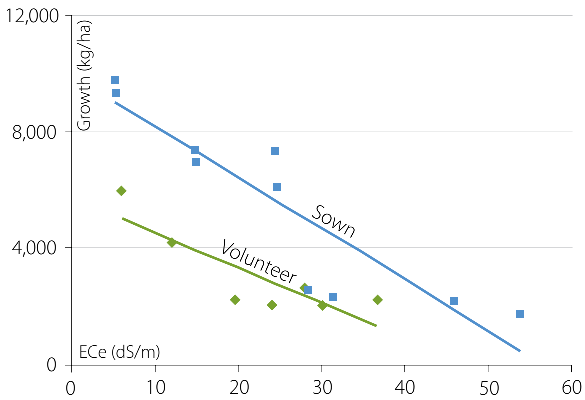
MOST LIKELY SITUATIONS

The concept of 'most likely situations' is used in the other Saltland Solutions to identify the niche where a particular saltland species is most likely to be suited. However, for this Saltland Solution it is not possible to nominate a 'suitable' mix of salinity and waterlogging – something will volunteer and form a 'pasture' in almost all situations.

However, recent research has led to the following general conclusions.

1. There are very few situations where this option is likely to fail – the exception being areas where there is major inundation, such as the beds of lakes or rivers. In many situations, it will be a viable option even if it is not the most profitable option.
2. The SGSL initiative has demonstrated that the difference in production between improved species and volunteer species gets smaller as sites become more severely affected by salinity and waterlogging. Figure SS2.1 shows this effect for sown and volunteer pastures at a site near Hamilton, Victoria. Similar data are available from a saltbush site near Tammin, Western Australia, where sown under-storey was no better than volunteer under-storey at high salinity levels.[16]
3. The economics of this option vary considerably depending on the site. Using whole farm economic modelling, different conclusions emerged for the wheatbelt of WA compared to the eastern States.[17]

Figure SS2.1: Pasture growth vs soil salinity (from a volunteer and a sown saltland pasture) at the SGSL site near Hamilton in Victoria. EC_e values were measured in the upper 10 cm of the soil profile.



In the summer dry areas of WA, there was little increase in whole farm profit from simply fencing saltland because the bulk of the volunteer pasture that established was from annual species that hay off in summer and provide little benefit in the late summer/autumn period when farm feed supplies are lowest. On the other hand, saltbush-based pastures can have a significant impact on this major feed gap – a benefit that declined with increasing areas of saltbush as the autumn feed gap was filled.

In the more temperate and summer rainfall areas from SA through to NSW, the modelling showed that simply fencing off saltland gave significant increases in whole farm profit, and that the net benefit increased as the area increased, indicating that the volunteer pastures were able to fill a feed gap(s).

In summary, this suggests that the fence and volunteer pasture option 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. In these cases, revegetation with non-grazing species (see Saltland Solution 11) should also be considered.
- Climatic zones where perennials rather than annuals are likely to establish – i.e. less Mediterranean climates – as the annuals will have a lesser impact on feed gaps.
- Larger areas of saltland in WA or smaller areas of saltland in eastern Australia.
- Any sites where risk of failure is thought to be high.
- Sites where available funds allow fencing but not pasture improvement.
- Sites where the farmer does not have the time or skills to establish a saltland pasture.
- Sites where the decision to sow an 'improved' saltland pasture may be taken at a later date.

THE BENEFITS

PRODUCTION

There are few records showing the actual production levels from volunteer pasture on saline land. Figure SS2.1 shows that for a saline site in western Victoria, the volunteer pasture produced about half the dry matter achieved by the improved pastures. In the absence of other data, this is probably a good 'rule of thumb'.

In another of the SGSL research projects, productivity of volunteer pasture was assessed at two sites in the wheatbelt of WA.[17]

The productivity of the volunteer pasture was similar across the two sites, providing an average of 914 kg of dry matter per ha (available in autumn) or an average of 255 grazing days per ha (for mature wethers). Merino sheep grazing unimproved saltland grew an average of 2.6 kg of clean wool/ha each year. The potential of the volunteer pasture is significantly under-estimated in this study because it was not grazed until autumn, as a comparison to saltbush-based pastures.

At Tammin, WA, the more saline site, the differences in biomass production between volunteer pasture and mature saltbush stands with volunteer under-storey were significant, but relatively small. The saltbush with volunteer under-storey provided 30% more grazing days in two of the three autumn grazing periods. Sowing improved under-storey species gave no additional gain.

At Yealering, WA, a less saline site, there were large differences between a saltbush-based pasture (saltbush and sown under-storey) and volunteer pasture. In autumn, the saltbush and sown under-storey area provided 2-4 times more grazing days per ha compared to volunteer pasture.

WATER USE

There are no research results available but it would be expected that volunteer pastures would typically use less water than sown saltland pastures. If high water use is a primary aim, then trees, shrubs and salt-tolerant and summer-growing grasses (such as tall wheatgrass) are likely to be the best option.

AMENITY AND ENVIRONMENTAL

As with the other potential benefits that may be associated with fencing and volunteer pastures on saline land, there is little or no scientific information available so we have to draw likely inferences from other saltland pasture species and situations.

One exception is the SGSL site in NSW, where the improvement in a control site (i.e. volunteer pasture) over time was recorded.[18] Between spring 2003 and winter 2006, the amount of bare ground in the volunteer pasture declined from 31% to 11%. This improved groundcover was the same as that achieved by the sown saltland pasture.

Farmer case studies[19] have consistently shown that while profitability is the major consideration in the way successful farmers run their businesses, it has a much lower impact on decisions associated with managing saline land. This is partly because most farms have salinity on only relatively small areas (the national average is about 20 ha but in the eastern States it is more likely to be 10 ha), and partly because saltland is a highly visible blight on the farm landscape.

The key to most of the amenity and environmental benefits from revegetating saltland is groundcover.

Michelle Hebart (right) and Liz Abraham examining species in a saline area that has been fenced to allow volunteer plants to establish.

Photo: John Barrie

For the environment, this involves reducing surface soil evaporation and salt build-up, protecting the soil from erosion, all as the basis for re-establishing some floral and faunal biodiversity. For amenity, this involves establishing green and growing plants on previously bare saline scalds. This improved visual amenity is a strong motivator for many farmers revegetating saline land, so if the primary goal of revegetation is not economic, then fencing and volunteer pasture can be a very attractive option.

An example of biodiversity improvement as a result of this saltland solution can be found as a link on the Saltland Genie website[21] – the report states: ... *significant environmental benefit (without loss of productivity) can be gained at low cost by simply changing grazing management on saline areas. Results from this grazing management approach show, in paddocks previously with significant areas of scalding, bare ground has been revegetated and species diversity has improved to a level equal to elsewhere on the property. In particular, these areas now contain more species of native perennial grasses than are present on other areas of the farm.*

HOW THE $$$s STACK UP

Under the fence and volunteer pasture option, the significant cost associated with establishing a pasture is simply not incurred. While the production from a volunteer pasture might be lower (a rule of thumb is that volunteer pastures might produce half the feed of a sown pasture), the fact that the costs are significantly lower can alter the overall economics. An economic analysis done as a part of SGSL on this solution[20] found:

- At the assumed levels of production, fencing saltland to control grazing was profitable in all regions. In WA, the benefit of fencing is low, about $15/ha, compared with $90/ha in NSW and $60/ha in SA.
- In NSW and SA, the increase in profit from fencing and volunteer pasture was higher than the subsequent increase in profit from pasture improvement. This is an important result as fencing provides a substantially cheaper option for management, with less risk of establishment failure and large potential benefits. However, this strategy is highly dependent on what species actually colonise the site. If the site is colonised by unproductive and unpalatable species, the result may be disappointing.
- In contrast, for a drier, more Mediterranean site in the wheatbelt of WA, the increase from fencing was much less than the subsequent increase from pasture improvement. The reason for this is that in Western Australia pasture improvement involves planting saltbush which enables the growth of considerably more forage that is available at a time when farm feed is in short supply, i.e. autumn.
- Total farm profit is higher from improved pasture than from the fence and volunteer pasture option but the cost and effort are also higher. The fence and volunteer pastures option resulted in a higher marginal return on the investment than that achieved for the improved pastures.
- As the costs associated with the fence and volunteer pasture option are significantly lower, the farmer is exposed to less financial risk.

Though not discussed in the report, the adoption of fencing and volunteer pasture does not preclude a later decision to improve the pasture, allowing a staging of the total expense over time if an improved saltland pasture is the ultimate aim.

A different economic analysis in NSW[21] showed that for one farm the return to extra capital invested in sown saltland pasture was around 14%, but the net present value was lower than for volunteer pasture on the saline area. This occurred because on a whole farm basis there is a significant cost associated with establishing the saltland pasture. On this farm, after year 1, the net cash flow for the sown pasture option was a total of $14,280 behind the net cash flow for the volunteer pasture because of the establishment costs. While the investment in the saltland pasture was profitable and was paid back by the fifth year of the sown pasture, the running cash flow balance from the investment failed to overtake the volunteer saltland pasture over the 10 years of the investment analysis.

There is the additional benefit with fence and volunteer grazing: a farmer's budget for saltland improvement will allow more saltland to be brought under good management than for other options that involve expenditure on pasture establishment.

HOW RELIABLE IS THE INFORMATION?

With only limited economic analysis of this option, confidence in, and the reliability of the information would typically be low. However, encouraging evidence about fence and volunteer pasture (overlooked in saltland literature to date), and its reduction or elimination of many costs and risks associated with establishing pastures on saline land, means this is not the case.

We can state reliably:

- Except in the most extreme salinity situations, the overgrazing of plants of limited vigour is the major cause of bare ground on saline land.
- While pasture establishment always carries a risk of failure, that risk is significantly magnified on saline sites.
- 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. In fact for the most highly saline and waterlogged areas, fencing off and removing all grazing is the recommended practice (see Saltland Solution 1).
- The likelihood of 'failure' from fencing off and allowing volunteer pasture to establish is almost zero.
- The costs associated with fencing and volunteer pasture are always significantly lower than if a specific saltland pasture is sown.
- Fencing and allowing a volunteer pasture to establish does not preclude a later decision to sow a pasture on the site.
- In eastern States, sites fenced off from grazing will often be colonised by tall wheatgrass if that has been established on saltland nearby. Other species that can establish naturally in more severely affected areas in WA are samphire, small leaf bluebush and puccinellia.

There are other aspects of the fence and volunteer pasture strategy that reflect a relatively low level of confidence in our knowledge:

- There has been no research to examine when volunteer pastures might be a better economic proposition than specifically established saltland pastures. However, as a general rule, the production advantage of sown saltland pastures over the 'controls' or volunteer pastures declines as sites become increasingly hostile due to salinity and waterlogging. This might indicate that the economics of volunteer pastures (compared to sown saltland pastures) rises with increasing salinity/waterlogging.
- Actual levels of pasture production from these volunteer pastures have rarely been measured.
- The composition of the volunteer pasture is hard to predict.
- The rate of establishment of the volunteer pastures has not been determined, nor has there been any study into the sorts of management that could increase this natural accretion of productivity.
- There has been no research into how grazing or other management might encourage either more desirable saltland species into the volunteer pastures or for it to happen more quickly.

THE RISKS AND CHALLENGES

In almost all the other Saltland Solutions, a major risk is associated with the fact that saline sites are hostile environments for most plants, and especially for establishing seedlings. This makes the risk of pasture establishment failure significantly higher than on non-saline land.

However, with this Saltland Solution, there is little or no risk of establishment failure. Fencing off a saline site from grazing will result in vegetation establishing there, which in most cases will be able to be grazed for at least part of the year. The only major exception to this is where the naturally establishing plant is samphire: these species can have ash concentrations in the leaves up to 40% and we would recommend that these plants not be grazed. To some degree, the susceptibility of saltland to major colonisation by samphire can be predicted. The seeds are generally carried in moving water – risk of inundation is therefore a driver – and samphires also have relatively specific requirements for subsoil salinity and depth to watertable, as outlined in Saltland Solution 1.

While there is some risk associated with the fact that the volunteer pasture that establishes will likely be less productive and/or less nutritious, and/or less profitable than if a saltland pasture was established, this risk is partly offset by the fact that the cost is minimised.

There is also some risk that the volunteer pasture will include significant weeds such as spiny rush. If this is the case, and weed control is needed, then the cost of the option will be increased.

In addition, the decision not to establish a sown saltland pasture can be reversed – the site has already been fenced, allowing sowing a purpose-designed saltland pasture at any time. The plant species that naturally colonise the area can be of great value as indicator species. A period of natural revegetation can give important clues to the best kinds of pasture species to sow in future.

Set stocking is never best practice on saltland because of the likelihood of overgrazing the most salty areas and turning them into bare saline scalds. Some form of rotational grazing will be the best option, but because the saline sites are often susceptible to pugging damage and erosion, it is recommended that stock be removed from the saline area when there is still significant groundcover.

In most cases, rotational grazing will give an advantage to perennial species over annuals and that is a good outcome for saltland – though there are significant perennial weeds that may invade some saline land, such as spiny rush.

Because different species will volunteer at different sites, apart from recommending conservative, rotational grazing, it is not possible to be more specific than to say grazing should be timed to avoid the seed-setting time for any plants that you wish to encourage.

Saltland Solution 3

Dense saltbush plantings

IN A NUTSHELL

This option refers to the growth of saltbush in dense (>1,000 plants/ha) plantations. These dense plantings are mainly old man and river saltbush (Australian natives), and sometimes include wavy leaf saltbush (introduced from Argentina), but all are *Atriplex* species established as either seedlings (lower risk but higher cost) or by direct seeding (higher risk but lower cost). These dense plantings all have some volunteer annual under-storey but the density of the planting severely limits the opportunity for under-storey species.

Profitability is typically quite low (~$5-6/ha), but the system has low maintenance costs after establishment and can persist indefinitely. Saltbush can be heavily crash-grazed as long as there is sufficient recovery time. Many systems are grazed back to the sticks every autumn as saltbush stands are a great place to supplementary feed sheep in autumn without risking soil erosion. Research has shown that saltbush should be grazed in autumn rather than left to drop leaves.[22]

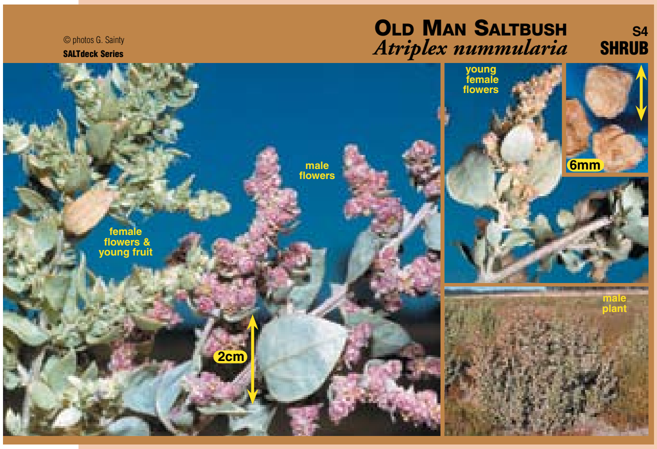
Dense saltbush plantings are suited to land of moderate-high salinity and little waterlogging. It is no longer widely recommended where Saltland Solution 4 – Saltbush and under-storey is possible. This is because Saltland Solution 4 has lower establishment costs, is more productive and profitable, and generally provides for easier management of sheep.

IDENTIFYING SALTBUSH

Saltbush are woody shrubs with leaves that accumulate significant amounts of salt that is noticeable when the leaves are tasted. The main saltbush species, with their SALTdeck identification cards, are:

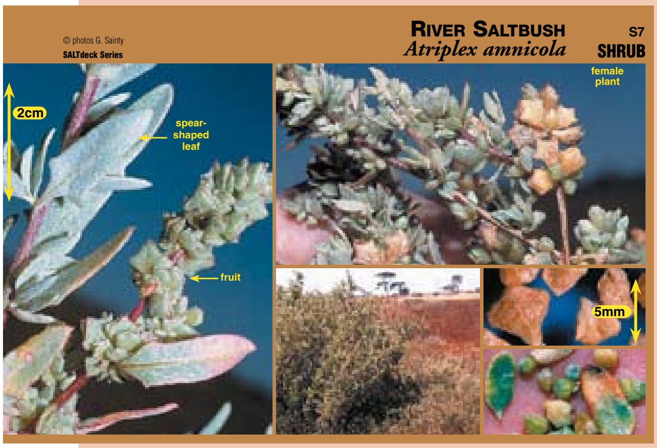
Old man saltbush (Figure SS3.1): A native of central and southern Australia, old man saltbush is an erect perennial shrub to 2 m tall and 1.5 m wide. Male and female flowers in terminal clusters, mostly on separate plants. Leaves are irregularly shaped and up to 4 cm across. Fruits are fan-shaped to roughly round and up to 6 mm wide. Its key features are the tall upright habit and leaf surfaces that are uniformly grey-green.

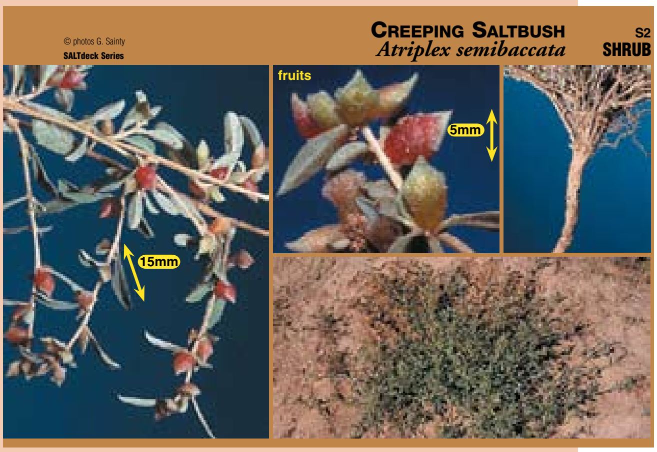
Wavy-leaf saltbush (Figure SS3.3): A native of central Argentina, wavy-leaf saltbush is a short-lived perennial shrub to 1 m high and up to 1.5 m wide. Stems are both erect and low spreading. Low stems trailing on the ground may form roots and new plants. Leaves are 0.5–2 cm long, occasionally to about 5 cm. Generally male and female flowers occur on separate plants. Fruits are round and soft containing one seed that matures in autumn. Its key features are the wavy (undulate) leaves and stems that are both erect and spreading.



River saltbush (Figure SS3.2): A native of Gascoyne and Murchison area, WA, river saltbush is a perennial shrub to 2 m tall and 4 m wide (although generally smaller) that can be prostrate or erect. Stems touching the ground may strike roots and form new plants. Leaves are 1-3 cm long. Generally, the male and female flowers occur on separate plants. Fruits are woody or papery 2–6 mm wide. Flowering varies with seasonal conditions. Key features are the leaves' variable shape but they are often characteristically spear-shaped.

Creeping saltbush (Figure SS3.4): A native to Australia and widespread in all mainland States, the creeping saltbush are short-lived perennials. It is a prostrate perennial shrub to 40 cm high. Male and female flowers occur in small clusters in the leaf axils. Plants grow as scattered individuals or in clumps and flower over summer. Its key features are the leaves which are green to grey-green above and whitish below, and the diamond-shaped fruit 4–6 mm long which are sometimes red and succulent when fresh.





See the SALTdeck cards for further information.[23]

MOST LIKELY SITUATIONS

LANDSCAPE NICHE

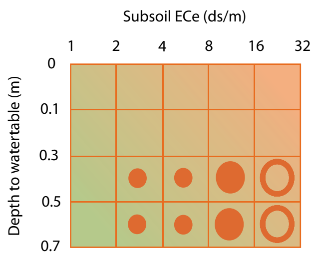
All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and where they are likely to thrive. For saltbush, these factors are summarised below.

Western Australia has the largest areas of saltland suited to saltbush. However, saltbush is highly relevant to the drier saline sites in SA, Victoria and NSW.

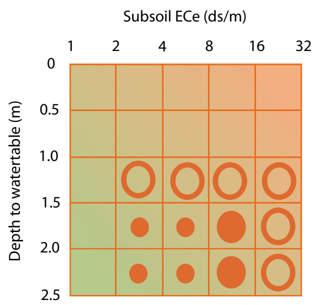
3 – MOST LIKELY SITUATIONS FOR DENSE SALTBUSH PLANTINGS

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER



SUMMER



DRIVERS OF PLANT ZONATION

- A halophyte and so does best with some salinity
- Sensitive to waterlogging, but can survive a higher watertable in winter than summer
- Growth in summer assisted if roots can access groundwater
- Summer grower, doesn't like the cold
- Rainfall 300-400 mm

Key to symbols

- ● (large) *This is the zone most preferred by saltbush and where it is highly recommended.*
- ● (small) *Saltbush is one of the possible options for this zone, but it is outside its preferred conditions.*
- ○ *Saltbush will most likely survive in this zone, but its growth will be poor and therefore is not recommended.*

COMMON INDICATOR SPECIES

Analysis of the indicator species growing on transect trials in Western Australia[24] project showed the following salt tolerance of common indicator plants (from lowest to highest): capeweed (*Arctotheca calendula)* < annual ryegrass (*Lolium rigidum)* < cotula/water buttons (*Cotula coronopifolia)* < iceplant (*Mesembryanthemum crystallinum)* < curly ryegrass (*Parapholis incurva)* < puccinellia (*Puccinellia ciliata*) < samphire (*Halosarcia* spp.).

Indicator plants can be misleading, especially those at the lower end of salinity tolerance. There may be many reasons (other than salinity) why a particular plant species is present at a particular location, e.g. grazing management, cultivation, herbicide use, the impact of recent weather events (especially out of season rainfall). Consequently, the presence of combinations of indicator plants will improve confidence in the site diagnosis. Annual plants (like iceplant) are likely to be better indicators of current conditions than perennial plants (such as puccinellia and samphire).

Plants in the range from capeweed to ice-plant are likely to indicate sites suited to dense saltbush plantings. See the SALTdeck[24] cards for the common indicator species mentioned above.

Sites with large areas of samphire are likely to be too salty and/or too waterlogged for either dense saltbush plantings, or for saltbush with under-storey unless the waterlogging can be corrected. Similarly, sites with large bare areas may be too salty and/or too waterlogged for saltbush, but such a diagnosis can be misleading if the site is part of a larger paddock and has bare areas as a result of overgrazing and stock camping rather than the bare areas being a true indicator of excessive salinity or waterlogging. On its own, ice-plant is regarded as a poor indicator, especially in Western Australia where it is becoming a more common weed in cropping paddocks.

SALINITY AND WATERLOGGING REQUIREMENTS

Salinity

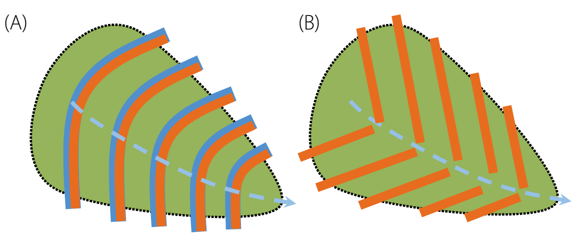
Dense saltbush plantings are recommended for soils with subsoils (25-50 cm) of 'high' salinity (EC_e values 8–16 dS/m). The higher the soil salinity, the greater the salt concentration in the saltbush and the greater the need for fresh water and supplementary feed when grazed. Dense saltbush plantings will grow and provide better feed at lower salinity levels. However, from an economic perspective this would generally be a sub-optimal use for the land unless other grazing benefits such as shade and shelter are particularly important.

Waterlogging

Much saltland can also be waterlogged, at least for part of the year. Despite being highly salt tolerant, saltbush is relatively sensitive to waterlogging and inundation particularly if it is prolonged or if it occurs during periods of high temperature. For more information see 'Getting real about Salinity'.[25] It is generally recommended that dense saltbush plantings be established at sites where watertables are deeper than 0.3 m in winter and deeper than 0.9 m in summer. Saltbush is able to access groundwater at this depth, but it requires less saturated conditions in the surface soil. Old man saltbush is generally more sensitive to waterlogging than river saltbush (watertables should be more than 0.5 m in winter and more than 1.1 m in summer).

As well as a watertable maintained below 0.3-0.5 m, good surface water management can also be critical for the successful establishment and long term survival of saltbush. This means choosing sites that either have limited inundation, or that can be easily modified so that surface water is not retained on the site. Planting the saltbush on mounds is a common method of reducing inundation, and the furrows associated with the mounds can further assist surface water movement. Arranging the mounds in a herringbone or fishbone pattern, with the rows sloping towards the natural drainage line, can greatly assist surface water flows from the site – see Figure SS3.5. Tall plants will generally survive inundation better than short plants.

Figure SS3.5: Use of herringbone design to alleviate waterlogging on a saline scald. (A). Saltbush rows 'on the contour' hold water back and become waterlogged. (B). Saltbush rows directed towards the drainage line in a herringbone layout shed water and alleviate waterlogging. Care may need to be taken to prevent erosion.



SOIL AND CLIMATIC REQUIREMENTS

Soils

Saltbush tends to grow best on soils that are lighter than heavy clays. In particular, direct seeding is only possible if the soil is sandy/loamy, or if there is a sandy/loamy layer over a heavy clay.

Soil acidity seems to be only a minor inhibiting factor for saltbush, except at extreme levels. Saltbush prefers alkaline soils and has decreased growth in acutely acid soils, though the evidence supporting this is largely anecdotal.

There may also be other soil nutrient issues but research has not yet been undertaken. However, waterlogging is far and away the most significant soil limitation for saltbush growing on saline land.

Rainfall

The suitable rainfall range for saltbush stands is approximately 250-450 mm. Below this range, the low production potential and high risk of establishment failure make dense saltbush plantings an uneconomic proposition. Above this rainfall range, there is a high likelihood that waterlogging will be a major constraint for saltbush. Good stands tend to be found in areas with 300-400 mm average annual rainfall.

Temperature

Saltbush is a summer grower and optimum growth occurs when daytime temperatures are in the range 30-35°C. Conversely, plants are usually dormant or slow growing during the colder months. With river saltbush little growth is evident when the mean daily temperature is below 13°C; with old man saltbush some growth can still occur in winter.

Anecdotal evidence suggests that old man saltbush has better tolerance to low temperature than river saltbush and will withstand quite severe frosts.

The overall result (especially with river saltbush) is that saltbush is not recommended for saline sites in the cooler and/or wetter areas across southern Australia.

Perennial grasses such as tall wheatgrass (link to Saltland Solution 5) and puccinellia (Saltland Solution 6) are better options.

PRODUCTION

Dense plantings of saltbush, growing in saline soils with salinity levels of 8-16 dS/m (i.e. the recommended range for this saltland solution) do not produce high levels of usable feed per hectare. It is easy to over-estimate the available forage supply in saltbush pastures because of the upright habit of the plants and because most of the 'dry matter' is the inedible woody stems.

As a general rule, the higher the density of saltbush planting, the smaller the individual saltbush plants will be and the smaller the contribution that under-storey species will make to total edible dry matter. Dense saltbush plantings (>1,000 plants per ha) are recommended where the salinity level is too high for productive under-storey species and so the aim is to maximise production of saltbush per hectare.

THE BENEFITS

To estimate dry matter availability of a stand of old man saltbush measure the widest diameter of 15-20 typical plants, provided they have been allowed to fully re-leaf since the last grazing. The estimated edible dry matter per plant (grams per plant) is the average diameter in centimetres, multiplied by 9.5 then minus 340. For edible dry matter per hectare, simply multiply the per plant estimate by the number of plants.

If the average bush diameter is 120 cm, there will be 800 g/plant and if there are 1,000 plants per hectare, the total available dry matter from saltbush would be 800 kg/ha. In the SGSL initiative,[26] grazing trials in Western Australia assessed the annual production from stands of old man and river saltbush. Averaged over two years, the sheep utilised ~400 to 600 kg of biomass per hectare from old man saltbush at a planting density of 930 plants per hectare. Each plant therefore produced an average of 430 to 650 g of edible biomass. Each river saltbush plant produced 570 to 800 g of edible biomass. Even in these dense saltbush stands the volunteer under-storey of annual grasses and herbs contributed about the same amount of edible biomass as the saltbush.

There are also some rules of thumb that can be used to estimate dry matter without the need for measurement. For an established and healthy stand of dense saltbush plantings, it can be assumed that each saltbush will have ~500 g of edible biomass per plant, available for grazing. In this type of situation, a sheep will need to be allocated one plant with its under-storey per day. In other words, a 10 ha stand of saltbush with 1,000 plants per hectare should support 500 sheep for at least 20 days, though it is likely that some additional supplementation with good quality hay or grain will be required to provide adequate nutrition for liveweight maintenance.[26]

Dense planting of old man saltbush. Photo: Barb Wolford

WATER USE

At sites where saltbush stands can draw the watertable down (e.g. local groundwater systems), surface soil conditions may be improved and the ability of a site to support a more productive and higher value under-storey enhanced.

This drawing down of the watertable can have a double-barrelled impact:

- By lowering the watertable, saltbush will reduce the amount of salt that the groundwater delivers into the root zone of the more shallow-rooted under-storey species, either by soil saturation or capillary action.
- Drying out the soil profile by lowering the watertable creates a buffer zone that enables winter rain to leach salt beyond the root zone. This, too, makes the site more suitable for productive under-storey species. The buffer zone, once established, has the added benefit of providing some protection for the saltbush against waterlogging or inundation following heavy or persistent rain.

During the late 1990s, anecdotal evidence from farmer experiences began to emerge in Western Australia that saltbush stands were making the sites more suitable for productive under-storey species. Research has now confirmed that in some situations (e.g. where the watertable is not too deep or too salty), saltbush stands are able to dry out soil profiles and lower watertables to some degree.[27]

Water use by saltbush will be affected by grazing management, since removal of the leaves from saltbush limits the ability of the plant to transpire water. The general principles are that water use will be greatest at times of high evaporative demand (high temperatures and low humidity typical of temperate summers) and when the plants are in full leaf. The ability of a stand of saltbush to use water will therefore be affected by the timing of grazing (plants grazed in late autumn will use more water than plants grazed in summer), and by strategic grazing management (plants that are crash-grazed and allowed to recover are likely to use more water than plants that are continually grazed through set-stocking).

AMENITY AND ENVIRONMENTAL

The amenity value of a well-managed stand of saltbush is unmistakeable and farmers take pride in this. Most of the evidence supporting environmental benefits from saltland pastures comes from farmer experience.[5]

Revegetation with saltbush can assist in reducing soil erosion, and can enhance flora and fauna diversity by providing habitat to small local birds, lizards and other small animals. There is some evidence of improved microbial activity in soils established to saltbush compared with bare areas. However, all of these potential benefits are dependent on how the saltbush is managed, particularly in terms of the grazing pressure, timing and seasonal conditions.[28]

Some of these benefits are assumed rather than based on well-documented research, and the possibility for negative impacts is apparent. For example, establishment of saltland pastures (saltbush-based in WA and perennial grass-based in NSW) led to an increase in salt export from the sites in the short term, caused by the soil disturbance associated with pasture establishment.[28] However, rates of salt export declined again after several years when the saltland pasture grew and the soil was no longer disturbed.

By far the most consistently reported environmental benefit of establishing saltland pastures is visual amenity. Although not easily measurable, farmers greatly value the improved visual amenity associated with replacing visibly salt-affected areas with productive groundcover.

OTHER BENEFITS

More so than other saltland pasture options, saltbush (either dense plantings or spaced rows with under-storey) can provide a substantial windbreak. These windbreaks increase stock shelter, and anecdotal evidence suggests such shelter can improve lambing percentages and reduce mortality in off-shears sheep. In addition, in areas prone to wind erosion, saltbush stands can support heavy stocking to the point where most groundcover is removed, but without significantly increasing the erosion risk.

Saltbush can also provide a feed reserve in tough seasons, giving greater control of the timing of sheep sales. In areas dominated by annual pasture, saltbush can take advantage of summer rainfall which may reduce the quality of other standing dry feed.

Some farmers place a high value on the capacity of the plants to decrease future salinisation. Saltbush can use significant amounts of groundwater and lower watertables at least slightly. The benefits of these effects in protecting cropping land from future salinisation are difficult to estimate but are only likely to be significant in flat landscapes with low rainfall.

HOW THE $$$s STACK UP

Farmer experiences and research results show that dense planting of saltbush is usually an expensive operation and rarely competes with other potential on-farm investments on an economic basis. However, when the benefits above are taken into account it may still be an attractive option.

An analysis of farmer trials from the Sustainable Grazing on Saline Land Producer Network[29] in the low rainfall zone of WA showed that profitability for dense saltbush plantings is almost certainly low. As shown in Table 6.1, with most assumptions, the payback period for this type of saltland pasture will be greater than 10 years and in many cases, even with modest discount rates, the original investment may never be repaid (i.e. a benefit: cost ratio of less than 1). The monetary value estimates in Table SS3.1 don't take into account some of the hard-to-measure benefits discussed above, but do include the associated infrastructure costs (things such as fencing and water supply) that further reduce the apparent profitability.

Profitability is most strongly influenced by both the cost of establishment and the subsequent productive performance. With good grazing management, saltbush is very long lived and the ongoing or maintenance costs are usually very low.

In the seven low rainfall case studies analysed in the SGSL initiative (WA sites), establishment costs varied from $77 to $787/ha. The establishment costs for dense saltbush plantings were highest when nursery-raised seedlings were used and lowest when the saltbush was direct-seeded. However, direct-seeding had a low success rate except in sandy soils, whereas a high success rate was usually associated with the more labour intensive planting out of seedlings.

VALUE AS SHEEP FEED

There has been a considerable research focus on the value of saltbush as a stock feed. Much of the criticism of saltbush pasture in the 1990s was related to its low nutritional value. As a sole diet, saltbush poses challenges for grazing animals because of its relatively low energy content and high salt concentrations. Part of the nutritional 'difficulty' is that standard laboratory tests of digestibility can greatly over-estimate feeding value because the soluble salt content (which can be 20% or more of the dry weight) is measured as part of the digestible fraction but contains no nutrition and restricts intake when it reaches 8-10% of the diet.

FARMER EXPERIENCES

A range of farmer case studies can be found on the Saltland Genie website[5] from across southern Australia where saltbush (either dense plantings or saltbush with improved under-storey) has become an integral part of the farm operation. The case studies are dominated by WA and SA examples as this is where the most extensive saltland plantings exist.

Table SS3.1: An analysis from the SGSL initiative showing estimated payback periods for low rainfall sites for a range of production levels (grazing days per ha) and values for a sheep grazing day.

Discount rate	Term of analysis	Grazing days per ha per year	Value of a sheep grazing day	Payback period	Benefit:Cost Ratio
5%	10 years	400	5 cents	> 10 yrs	0.21
			10 cents	> 10 yrs	0.42
			15 cents	> 10 yrs	0.63
		800	5 cents	> 10 yrs	0.42
			10 cents	> 10 yrs	0.84
			15 cents	7 years	1.25
9%	10 years	400	5 cents	> 10 yrs	0.18
			10 cents	> 10 yrs	0.36
			15 cents	> 10 yrs	0.54
		800	5 cents	> 10 yrs	0.36
			10 cents	> 10 yrs	0.72
			15 cents	8 yrs	1.08

ESTABLISHMENT AND MANAGEMENT

CHOOSING THE RIGHT SPECIES AND VARIETIES

While selecting the right species and varieties can be important, in most situations farmers establishing saltbush will have little practical control.

Species

The three most important saltbush species used in Australia are old man saltbush (*Atriplex nu mmularia*), river saltbush (*A. amnicola*) and wavy leaf saltbush (*A. undulata*). Mixtures of species are often sown with direct-seeding to reduce the risk of establishment failure. However, the grazing management of mixtures can be problematic. Nursery-raised seedlings are invariably planted as single species stands, usually river and/or old man saltbush.

Seed sources

Nearly all stands of saltbush are planted from what are essentially wild sources of seed, giving rise to high variability in characteristics such as palatability and productivity. There have been limited attempts to select germplasm. Old man saltbush is octoploid, so it is likely to be exceptionally genetically diverse and specific traits will be difficult to maintain across generations. The pedigree of material sold today as descendents of the selections described above would have to be regarded as doubtful.

Clones

Tamlin's Nursery in South Australia currently market a clone of old man saltbush called Eyres Green' claimed to have rapid recovery from grazing with good palatability, digestibility and high protein. Some farmers in WA have trialled Clone 28 from the river saltbush collection of the WA Department of Agriculture and Food. It produces a huge amount of dry matter but a lot of it is in woody shoots and the clone recovers poorly from grazing.

ESTABLISHMENT TECHNIQUES

Before establishing dense saltbush plantings, significant planning is required. As discussed previously the layout needs to ensure that surface drainage is not impeded and can be enhanced by planting mounds. In addition, mustering stock in dense saltbush plantings can be difficult unless the planting layout includes laneways at least 5 m wide for vehicle and animal access.

Growing a good saltland pasture should be approached just as another agricultural activity and is based on many of the skills already used with other crops or pastures. Good site preparation, weed control, insect control, timing and grazing management is essential.

Establishment of any seed is a risky process. On non-saline land, germination and establishment success is routinely challenged by drought, frost, insect attack, and weed competition. On saltland, there are additional risks associated with salinity, waterlogging and inundation.

There are two ways of establishing saltbush: niche seeding (growing saltbush directly from seed) and the planting of nursery-raised seedlings with a tree planter.

Direct-seeding should only be used on soils with low to moderate salinity and a sandy surface soil. Nursery-raised seedlings are more versatile and can be grown on more saline soils and with a wider range of textures. If the site is suited to either method, then there is a trade-off between cost and reliability. If the site is large, then the lower costs associated with direct seeding might be compelling, but if the site is small the increased reliability of the seedlings could be a better option.

NURSERY-RAISED SEEDLINGS

Saltbush seedlings are available from a number of nurseries in WA and the eastern States. The seedlings are usually planted with a commercial tree planter

Method

Spring of the year before planting. The site should be no more than highly saline, with an EC_e in the subsoil of 8-16 dS/m. On less-saline sites other options, such as saltbush with improved under-storey, should be investigated. If the planting mounds are established prior to planting, make sure the mounds do not hold back the drainage of surface water. The layout should be designed to assist surface drainage. Red-legged earth mites love saltbush seedlings, and can be partly controlled in the spring of the preparation year by spraying as close as possible to the optimal Timerite® spraying date.[30]

Year 1 – Planting the saltbush. Wait until the risk from waterlogging has abated (August to October depending on location and climate). Apply a knockdown herbicide, cultivate and then plant the saltbushes. Monitor for red-legged earth mite and spray promptly as needed.

Grazing. For dense saltbush stands with no under-storey, light grazing can commence in the first autumn after planting.

The cost of establishment using nursery-raised seedlings will depend on the price per plant, the density of planting, planting costs (including spraying and cultivation) and any costs associated with the pre-preparation of the site, plus the cost of providing infrastructure like fences and sources of stock water.

DIRECT SEEDING OF SALTBUSH

Saltbush can also be established from seed using a niche seeder to place the seeds mixed with vermiculite at 2–3 m intervals along the top of a raised M-shaped mound. Raising the mound reduces waterlogging and vermiculite acts as a mulch, reducing the movement of salt to the soil surface by capillarity.

Method

Spring of the year before planting. The site should be no more than moderately saline (EC_e in subsoil of 4-8 dS/m) with a sandy surface soil. In the year before planting, spray-top with a knockdown herbicide to prevent seed-set by annual grasses. Plan the layout to ensure that the mounds established by the niche seeder will not hold back surface water and any additional surface water management structures are installed. Red-legged earth mite can be partly controlled in the spring before sowing by spraying as close as possible to the optimal Timerite® spraying date.[31]

Year 1 – sowing the saltbush seeds. Wait until the soil has warmed and the risk of waterlogging has abated (August-September, depending on location and winter rainfall). Apply two knockdown herbicides – glyphosate four weeks before seeding, and SpraySeed® two days before seeding. Cultivate just before niche seeding. After seeding, look carefully for damaging insects as saltbush seedlings are very vulnerable to attack from these insects. Spray *immediately* if red-legged earth mites, aphids or native budworm are present. Check weekly for 10-15 weeks. More than one spray may be required.

Researchers at Kings Park Botanic Garden in WA have found that priming river saltbush seed with smoked water significantly increases germination rates by breaking seed dormancy. This technique has been used to stimulate germination of many native flora seed, but has not delivered similar results for old man saltbush or for wavy leaf saltbush. Further research is exploring other practical options. Researchers at Kings Park have also made progress developing seed coatings that inhibit the mass removal of seed by ants.

Grazing. Light grazing of dense saltbush stands with no under-storey can begin in the first autumn after planting.

The cost of establishment from niche seeding will depend mainly on the cost of seed and vermiculite and the costs associated with preparing the site, hiring a seeding machine and providing infrastructure (such as surface drains, fences, sources of stock water).

In some regions, contractors are available to do niche seeding. Contract rates can be about $150–$200/ha.

TIMING OF ESTABLISHMENT

In most areas the timing of saltbush establishment is a balance between going early (late winter, very early spring) or late (spring). The general issues apply to both nursery-raised seedlings and direct-seeding, but timing is far more critical for direct-seeding as the following example shows.

The timing of direct-seeding must be adapted to the seasonal conditions prevailing at the time. The advantage of early seeding or early planting (late winter or early spring) is that the small plants have an opportunity to establish sufficiently to survive the likely high temperatures and low rainfall of the first summer. However, seeding early can be extremely difficult if the site is wet, and most salty sites are very wet at that time of year. Moreover, if seeding occurs too early there is a risk of failure because of waterlogging damage from subsequent rainfall. River saltbush in particular is likely to germinate very slowly at average daily temperatures less than 10°C.

If seeding is delayed into the spring, establishment can be significantly better as low temperature and waterlogging shocks are much less likely. If sown too late, the small establishing plants are unlikely have root systems that are sufficiently developed to allow the plants to survive as the soil dries out and becomes more saline over summer.

The decision on when to sow or plant will depend very much on the year. Salt-affected sites can become untrafficable. On the other hand, an early finish to the season can leave the site highly saline and with little or no rainfall for several months.

MANAGEMENT NEEDS AND TIPS

Early stages

When first established, saltbush seedlings are quite vulnerable. Saltbush seedlings are very poor competitors and they must be protected from weeds, insect pests and grazing animals (including rabbits and kangaroos) during their early development. Annual weeds can be controlled by over-spraying well-established saltbush with gyphosate at approximately 1 L/ha. Once firmly established, little further input (apart from grazing management) is required. Individual plants of old man saltbush are very long lived.

First grazing

Most saltbush planted in early spring will be large and robust enough to graze during the following autumn. This first grazing should be lighter than subsequent grazings, and should be carefully monitored to ensure the stock are removed when there is still significant leaf remaining on the bushes, and before any damage to the main branches.

Fencing

Grazing control during establishment is critical. Many farmers can save on a fence at the outset by planting saltland while the rest of the paddock is in crop. Then the investment in fencing only needs to be made once the level of establishment – and the likely value of the pasture – can be seen.

Fertiliser

While it is likely that saltbush would respond to fertiliser, it is rarely applied in practice. Little is known about the availability of soil nutrients in saline sites, and because the edible yield from dense saltbush plantings in saline soils is quite low (usually less than 1,000 kg of edible material per ha), applying fertiliser is not usual practice.

Pests and diseases

Many saltbushes (not wavy leaf) are native to Australia and therefore have a range of local insects and diseases that eat or attack them. Mostly, pest and disease attacks are episodic and plants generally recover satisfactorily. Reports of major pest or disease damage are relatively rare. The exception is insect attacks on seedlings (especially by mites, aphids and budworms) that, if not controlled, can kill many seedlings. Locusts can do significant damage in a short time. In the face of clear evidence of an advancing locust swarm it can be prudent to crash-graze the saltbush so as to make use of the green matter while it is still there.

Rotationally grazed saltbush planting. Photo: Hayley Norman

GRAZING OPTIONS AND MANAGEMENT

There is little research comparing different grazing management options for dense saltbush plantings, but there is considerable farmer experience from both saline land and native saltbush areas in the rangelands. The different species of saltbush vary to some degree in palatability and ability to recover from grazing (Table SS3.2).

Once established, saltbush can withstand very hard grazing and the most common practice with dense saltbush plantings on saltland is for annual crash-grazing where the bushes are effectively grazed back to the twigs each autumn. Saltbush recovers well, as long as it is allowed sufficient time. Constant heavy grazing will eventually weaken and kill most saltbush.

Some farmers do not graze their saltbush each season, preferring to save the feed for less productive seasons. However, research in Western Australia has shown that heavy grazing of mature old man saltbush in autumn has little detrimental impact on the amount of edible dry matter that is available at the start of the following autumn compared to an ungrazed control. The research showed that old man saltbush drops a lot of leaves when left ungrazed, so that there is little advantage in deferred grazing between years.[32]

Regular (at least annual) grazing of saltbush is essential or the individual bushes quickly exceed sheep grazing height if growth conditions are good. Once this occurs, future growth will be preferentially directed to the area where grazing is no longer possible and the value of the saltbush stand may be reduced. Some form of pruning may be needed, though grazing with cattle can assist in reducing the top growth, and anecdotal evidence suggests that sheep get very good at dragging the saltbush down to graze. Mechanical pruning is expensive, but if undertaken, cutting the bushes back to about 60 cm in height is an effective way to restore the stand to full productivity. It is important not to over-emphasise this as annual grazing will mostly keep saltbush within sheep grazing height. In addition, some leaf left above sheep height and not grazed will allow the saltbush to keep using water even when heavily grazed.

Table SS3.2: Some characteristics of different saltbush species.

Common Name	Species Name	Tolerance to:		Palatability	Grazing recovery	Suitability for direct seeding
		Salinity	Waterlogging			
Old man saltbush	*Atriplex nummularia*	xxxx	xx	xx	xxxx	xx
River saltbush	*A. amnicola*	xxxx	xxx	xxxx	xxxx	xx
Wavy leaf saltbush	*A. undulata*	xxxx	xxx	xxx	xx	xxxx
Quail brush	*A. lentiformis*	xxxx	xxx	xxxx	xxx	xxx
Key xxxx (high), xxx (moderate), xx (low)						

INTEGRATION INTO FARMING SYSTEMS

Dense saltbush plantings are seldom a good investment if the only benefit will be feed production. However, farmers claim a range of other benefits when saltbush is considered as part of their overall farming system. Indeed, farmer experience (now backed up to some extent by economic modelling) suggests that about half the value from saltland pastures comes from the direct feed input, and the other half comes from the range of other benefits to the whole farm system.

The major production benefits of dense saltbush plantings flow primarily from their ability to provide green feed at times when it is otherwise not available (usually late summer and autumn in southern Australia) and the fact that they are using land of very little other value. Dense saltbush plantings can significantly decrease the requirement for hand feeding, especially in summer and autumn.

Dense saltbush plantings are an ideal holding area (or sacrifice paddock) during periods of intensive supplementary feeding and/or after the autumn break to allow other pastures (especially annual pastures or pasture components that have to germinate and establish) to get away elsewhere on the farm.

Shelter for lambing ewes can be a further benefit, but a possible downside is that it can become more difficult to monitor lambing in dense stands of saltbush. Saltbush can offer emergency shelter for off-shears sheep, but there is the risk of saline sites becoming very wet when shelter is needed.

The growth of saltbush can increase the resilience of farm businesses to drought and flood and these benefits are widely ignored in the bio-economic modelling.

ANIMAL NUTRITION ISSUES

Research shows that livestock grazing saltbush alone will not get sufficient nutrients for maintenance, but with appropriate supplementation, saltbush can be used for both sheep and cattle. The critical issue is the high salt concentration in the saltbush leaves and stems – as much as 30% in extreme cases. If grazing sheep the use of these shrubs as the sole feed supply presents a major nutritional challenge. As salt in the feed increases, appetite is suppressed, intake decreased and digestion disrupted. Sheep cope well with less than 10% of the diet as salt or with a total salt intake of less than 100 g/d. At salt intakes between 150 and 250 g/d (which might represent as little as 500 g of saltbush dry matter) sheep will reach an upper limit in their ability to process and excrete salt.

Energy

Saltbush has relatively low metabolisable energy (less than that required for a maintenance diet for sheep or cattle). The energy value of saltbush can be over-estimated (by up to 30%) if standard laboratory measurements are not corrected for the high salt content which is soluble and so appears to be digested. Saltbush leaves are reasonably digestible but small stems make up much of the edible portion of saltbush.

When eating feeds with an energy level similar to saltbush, animals would normally attempt to increase their intake. A 50 kg sheep would need to eat more than 1 kg/d of a straight saltbush diet to maintain condition. This is impossible with saltbush because the high salt concentration in the feed limits intake to about 800 g, depending on the level of salt in the soil and in the plant's leaves.

Protein

Saltbush appears to have a very high crude protein content (typically 12-20%). This is a very valuable feature, especially in summer and autumn when green feed (and therefore protein) can be very limited on farms. Crude protein is calculated from the nitrogen concentration in the leaves because in normal pasture plants most of the nitrogen is contained in protein molecules. However, about half the crude protein in saltbush is not protein at all, but nitrogen contained in a range of other compounds, primarily those that are used to assist the plant cells manage the high salt loads. This non-protein nitrogen can be converted into microbial protein in the rumen if there is a good supply of energy available. This is unlikely to be the case for livestock grazing dense saltbush plantings with little or no under-storey without a significant energy supplement.

Salt

Sheep will select a diet that balances the need for high nutrient intake against the cost of managing a salt load. Salt, protein and energy content of a feed all interact to drive diet selection. The feeding value of a high-salt diet can be improved by offering low-salt alternatives and sheep will actively select quantities of high and low salt feeds that improve the feeding value of their diet.

Water

For sheep to cope with high levels of salt in the diet they must have access to a large supply of high-quality drinking water. If the drinking water also contains salt, then the ability of livestock to eat large amounts of saltbush is further reduced. In one study, feed intake of sheep on old man saltbush fell by more than half when the drinking water was replaced by water containing 1% salt (10,000 ppm). Though it varies considerably with temperature, wind exposure and distance walked to water, sheep typically drink 3-4 litres of water per day when eating a non-salty, dry feed. By contrast, sheep need to drink about 4 litres of extra water for every 100 g of salt (or approximately 350 g of saltbush) that they consume.

Vitamin E

Dried annual pastures can be highly deficient in vitamin E, which can cause a muscle wasting disease in sheep. Research in Western Australia has shown that old man saltbush is an excellent source of vitamin E, containing about 250 mg vitamin E per kilogram of green leaf. Vitamin E is also associated with improved meat quality.

Increased salt and wool growth

Salty diets can increase the efficiency of wool growth by up to 20%. It has been hypothesised that these benefits come from the increased salt in the diet causing increased passage through the gut which prevents the rapid destruction of protein in the rumen. It seems likely that saltbush in the diet would have a similar effect. These effects have not been taken into account in the MIDAS modelling.

SUPPORTING RESOURCES

Barrett-Lennard, Ed. Saltland. *Pastures in Australia – a practical guide*. Available from http://www.landwaterwool.gov.au/products/pr030563.

Liddicoat, C. and McFarlane, J. (2007). *Saltland Pastures for South Australia.* Department of Water, Land and Biodiversity Conservation Report No 2007/08. This is a product of the SGSL initiative, providing a wealth of information that will be of value beyond SA. It can be ordered from http://www.landwaterwool.gov.au/products/px071257-0.

Masters, David G., Benes, Sharon E. and Norman, Hayley C. (2007). Biosaline agriculture for forage and livestock production. *Agriculture, Ecosystems and Environment* **119**, 234–248.

Stevens, J.C., Barrett-Lennard, E.G. and Dixon, K.W. (2006). Enhancing the germination of three fodder shrubs (*Atriplex amnicola*, *A. nummularia*, *A. undulata*; Chenopodiacease): implications for the optimisation of field establishment. *Australian Journal of Agricultural Research*, 57, 1279–1289.

Saltland Solution 4

Saltbush and under-storey

IN A NUTSHELL

Much of the original published information about saltbush focused on dense saltbush plantings (see Saltland Solution 3). Over time, however, it has become clear that where an annual under-storey between the saltbush rows is possible, the under-storey provides the bulk of the feed for grazing animals. In this scenario, saltbush is usually sown in multiple rows, with a wider alley between the sets of rows for the under-storey. This makes it a cheaper option as well as allowing easy vehicle access and livestock management. In this configuration, saltbush may have 500-600 plants per hectare but this can vary widely depending on the width of the alley ways. Old man saltbush and river saltbush are the best species for this system. Old man saltbush supports slightly better animal performance and does not spread across into the inter-row. River saltbush tends to be more tolerant of transient waterlogging.

Saltbush and under-storey is now the option most recommended for low rainfall sites, most of which are in the WA wheatbelt, but significant opportunities are available in the drier wheat growing regions of SA, Victoria and NSW.

Saltbush in the saltbush and under-storey system has two key roles:

- Using water over summer to dry out the soil and draw down the watertable so that the surface soil can be more readily leached of salt. If saltbush can draw down the watertable even slightly (e.g. 20-30 cm), this can make a substantial difference to the surface soil conditions and the ability of a site to support a more productive and higher value under-storey.
- Providing some green feed in autumn, at a time when most farms in the rainfall zone suited to this option will have only dry standing feed. It has been estimated that green feed in autumn in the WA wheatbelt has a value 10 times that of the same feed in spring.

The saltbush used in this option are mainly old man and river saltbush (Australian natives), and sometimes wavy leaf saltbush (introduced from Argentina). These are established as either seedlings (lower risk but higher cost) or by direct-seeding (higher risk but lower cost).

The under-storey in the saltbush and under-storey system also has two key roles:

- The primary role is to provide feed for livestock in as greater quantity and of the best nutritive value possible.
- A secondary role is 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.

The under-storey species used in this option will grow best at low soil salinities (subsoil EC_e values of 2-4 dS/m) but may tolerate moderate salinity levels (subsoil EC_e values of 4-8 dS/m). A mixture of improved species is usually the best option, involving (depending on location, rainfall, etc) annual legumes (such as balansa clover, sub-clover, burr medic) and grasses (such as annual ryegrass). At high salinity levels (subsoil EC_e values of 8-16 dS/m) the improved under-storey species will be beyond the limit of their salinity tolerance so dense saltbush plantings become the recommended option (see Saltland Solution 3). Simply allowing an under-storey of volunteer species is also an option but the under-storey will tend to be dominated by sea barleygrass.

The profitability of this system can be substantially higher than for dense saltbush plantings because of the lower establishment cost and higher carrying capacity.

SALTBUSH SPECIES

The saltbush species have been described in some detail in Saltland Solution 3 – Dense saltbush plantings.

As with dense saltbush, this option is suited to sites with little waterlogging – many of the possible under-storey species are quite tolerant of waterlogging, but in such conditions, the saltbush will not thrive and may not even survive. Where waterlogging is likely, the salt tolerant grasses are likely to be a better option (see Saltland Solution 5 – Tall wheatgrass, Saltland Solution 6 – Puccinellia and Saltland Solution 7 – Vegetative grasses).

Figure SS4.1: SALTdeck identification card for balansa clover.

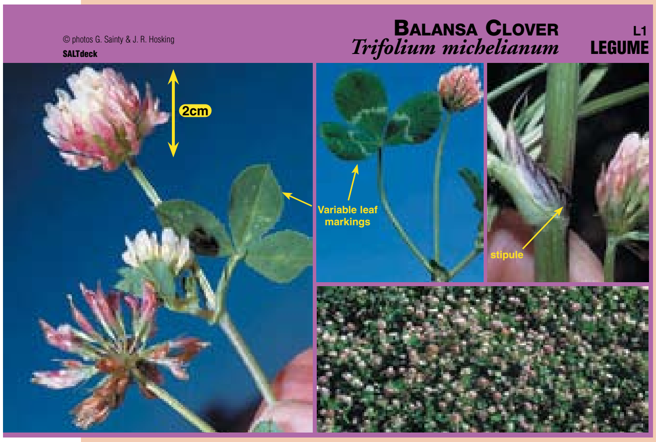


Figure SS4.2: SALTdeck identification card for barrel medic.

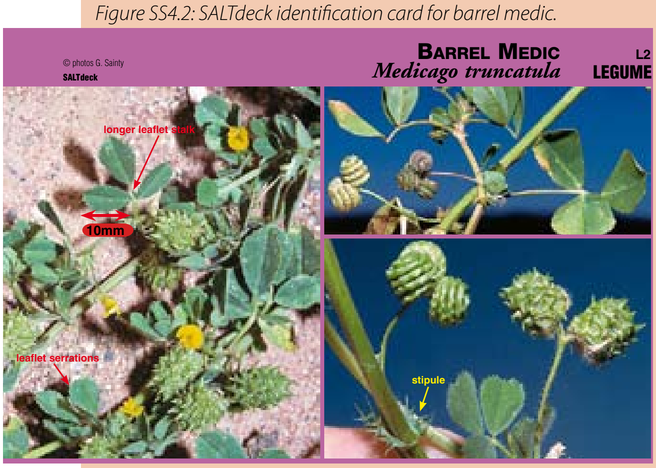
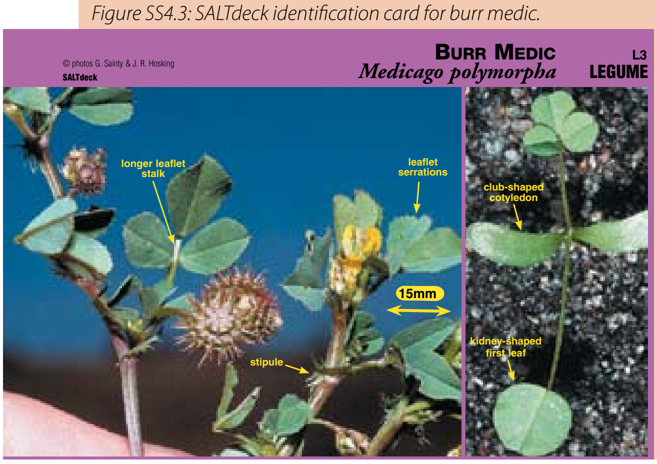


Figure SS4.3: SALTdeck identification card for burr medic.



Recommendations for what should be included in a sown under-storey are not so clear.

- If the site is suitable for saltbush, then puccinellia (see Saltland Solution 6) will not thrive because it prefers waterlogging.
- If the site is suitable for tall wheatgrass (see Saltland Solution 5) then it is probably a better perennial option than saltbush. It is more productive and better nutritionally.
- If the site is suitable for either the temperate or subtropical grasses with limited salinity tolerance (see Saltland Solutions 8 and 9) then they are probably a better perennial option than saltbush.

Annual pasture species (legumes and grasses) are probably the best under-storey option for saltbush pastures in the 300 to 450 mm rainfall zone. They can take advantage of the improved environment created by the saltbush but do not compete for moisture over summer. The most frequently recommended annual species for sowing as under-storey in a saltbush based pasture are balansa clover, burr medic and barrel medic, plus annual and Italian ryegrasses. For more detail on these species see SALTdeck.[33]

Figure SS4.4: SALTdeck identification card for annual ryegrass.

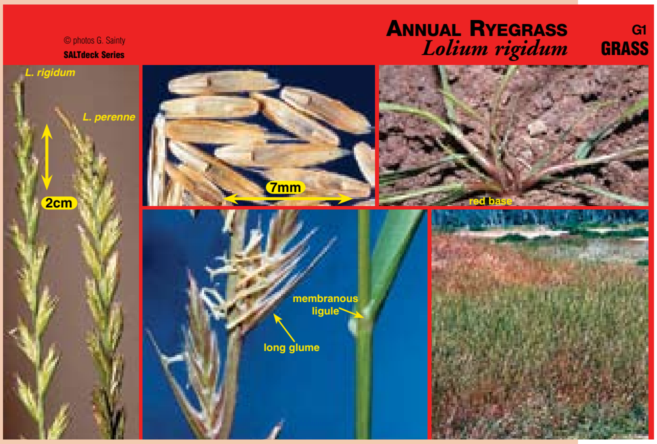
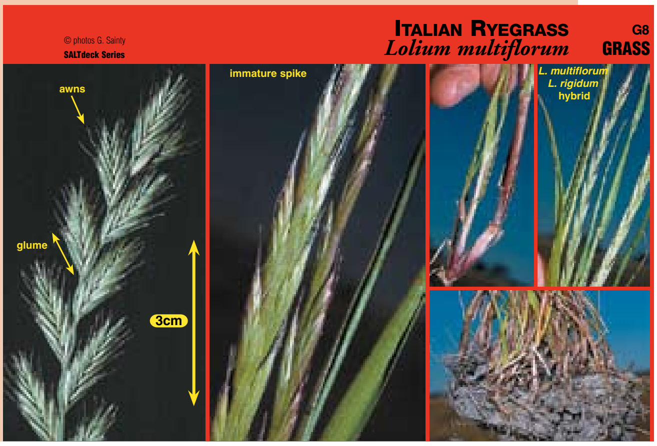


Figure SS4.5: SALTdeck identification card for Italian ryegrass.



MOST LIKELY SITUATIONS

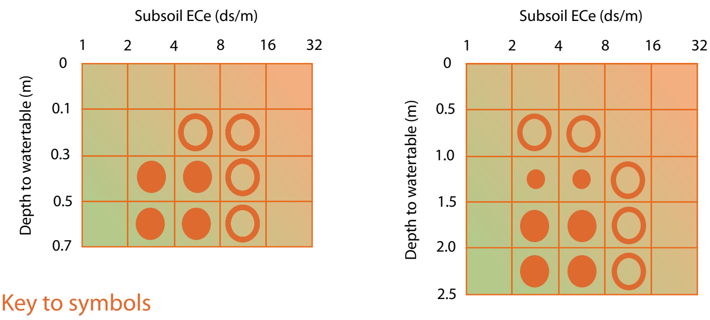
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or where they will perform best. Saltbush and under-storey plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and are likely to thrive. As this is a mixed option, some compromises are necessary, but overall for saltbush and under-storey, these factors are summarised below.

4 – MOST LIKELY SITUATIONS FOR SALTBUSH AND UNDER-STOREY

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER — SUMMER



DRIVERS OF PLANT ZONATION

- Halophyte (saltbush) and non-halophytes (under-storey) with differing tolerances to waterlogging
- Compromises required!
- Saltbush growth in summer assisted if roots can access ground water
- Most likely rainfall 300-450 mm

Key to symbols

- (large solid circle) *This is the zone most preferred by saltbush and under-storey and where it is highly recommended.*
- (small solid circle) *Saltbush and under-storey is one of the possible options for this zone, but it is outside its preferred conditions.*
- (open circle) *Saltbush and under-storey will most likely survive in this zone, but its growth will be poor and therefore is not recommended.*

COMMON INDICATOR SPECIES

Identifying sites that are suited to the saltbush and under-storey mixture involves finding a compromise between where saltbush will grow and where the sown under-storey species can make a significant contribution (i.e. more so than a volunteer under-storey). Indicator species such as curly ryegrass that can tolerate sites with high salinity are indicative of locations that will be too salty for the under-storey species. Indicator species (such as cotula, marine or saltwater couch, puccinellia or samphire) that can tolerate high levels of waterlogging are indicative of sites where the saltbush is likely to struggle.

In between these two extremes, there are some species, that if present, are likely to indicate the ideal mix of salinity and waterlogging for a saltbush and under-storey pasture. These include capeweed, annual ryegrass, sea barleygrass, barley grass and annual legumes such as woolly clover or burr medic (see SALTdeck[10] for further details). Capeweed was not included in SALTdeck because it has quite low salinity tolerance.

It must always be noted, that indicator plants can be misleading, especially those at the lower end of salinity tolerance. There may be many reasons (other than salinity) why a particular plant species is present at a particular location (e.g. history of grazing management, cultivation, herbicide use, and impact of recent weather events, especially out of season rainfall). Similarly, sites with large bare areas may be too salty and/or too waterlogged for saltbush and under-storey, but such a diagnosis can be misleading if the site is part of a larger paddock and has bare areas as a result of overgrazing and stock camping rather than being a true indicator of excessive salinity or waterlogging.

SALINITY AND WATERLOGGING REQUIREMENTS

Salinity

Saltbush and under-storey is the recommended option for sites of moderate salinity (subsoil EC_e values of 4-8 dS/m) in the 300-450 mm rainfall zone, but it can also be recommended for sites of low salinity (subsoil EC_e values of 2-4 dS/m) if the rainfall is too low to support perennial grasses.

Waterlogging

Much saltland can also be waterlogged, at least for part of the year. Despite being highly salt tolerant, saltbushes are relatively sensitive to waterlogging and inundation, especially if it is prolonged or if it occurs during periods of high temperature. Some under-storey species (e.g. balansa clover) are highly waterlogging tolerant, while others (e.g. burr medic) are more like saltbush. As a package, saltbush and under-storey is not suited to highly waterlogged sites because the saltbush will not survive.

It is generally recommended that saltbush and under-storey be established at sites where watertables are deeper than ~0.3 m in winter and deeper than ~1.5 m in summer. Old man saltbush is generally more sensitive to waterlogging than river saltbush (watertables should be more than 0.5 m in winter).

As well as a watertable maintained below 0.3-0.5 m in winter, good surface water management can also be critical for the successful establishment and long term survival of the saltbush component of the pasture. This means choosing sites that have either limited inundation, or that can be easily modified so that surface water is not retained on the site. Planting the saltbush on mounds is a common method of reducing inundation, and furrows associated with the mounds can further assist surface water movement from the site. However, layout design is critical. Mounds in a herringbone layout can decrease waterlogging, but mounds on the contour that collect runoff can make a waterlogging problem worse (see Figure SS4.6).

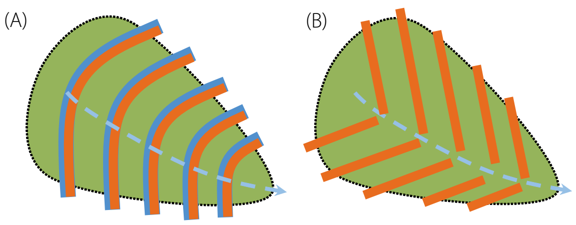


Figure SS4.6: Use of herringbone mounding design to alleviate waterlogging on a saline scald. (A). Saltbush rows on the contour hold water back and become waterlogged. (B). Saltbush rows directed towards the drainage line in a herringbone layout shed water and alleviate waterlogging.

SOIL AND CLIMATIC REQUIREMENTS

Overall, the climatic requirements for the under-storey species are less precise than for saltbush, so the saltbush and under-storey combination is restricted to those areas where saltbush is suited.

Rainfall. The suitable rainfall range for saltbush stands is approximately 250-450 mm. Below this range, the low production potential and high risk of establishment failure make saltbush an uneconomic proposition, while above this rainfall range, there is a high likelihood that waterlogging will be a major constraint for saltbush. Good saltbush stands tend to be found in areas with 300-400 mm average annual rainfall and this zone is the major target for saltbush and under-storey combinations.

Temperature. Saltbush grows optimally when daytime temperatures are warm (around 30°C). Conversely, plants are usually dormant or slow growing during the colder months. With river saltbush little growth is evident when the mean daily temperature is below 10°C; with old man saltbush some growth can still occur in winter.

The overall result is that saltbush and under-storey is not recommended for saline sites in the colder and/or wetter areas across southern Australia. In these areas, the perennial grasses such as tall wheatgrass (see Saltland Solution 5) and puccinellia (see Saltland Solution 6) are usually better options.

Soils

Saltbush tend to grow best on soils that are lighter than heavy clays. In particular, direct seeding is only possible if the soil is sandy/loamy, or if there is a sandy/loamy layer over a heavier clay.

Soil acidity seems to be only a minor inhibiting factor for saltbush, except at extreme levels. Saltbush prefers alkaline soils and has decreased growth in acutely acid soils, though the evidence supporting this is largely anecdotal. By far the most restricting soil issue for saltbush is waterlogging.

THE BENEFITS

PRODUCTION

Saltbush does not produce high levels of utilisable feed per hectare, whether growing in dense plantings, or as part of a 'saltbush and under-storey' system. It is easy to over-estimate the available forage from saltbush because of the upright habit of the plants and because most of the standing dry matter is made up of low nutritive value twigs (which may be eaten but the animals get no net benefit because of the low digestibility), and the inedible woody stems.

An easy rule of thumb is to simply allow half a kilogram of edible material per saltbush plant that is well leafed and where the growth is not above sheep height. For edible dry matter per hectare, simply multiply the per plant estimate by the number of plants per hectare.

In the SGSL initiative, grazing trials in Western Australia assessed the annual production from stands of old man and river saltbush. Averaged over two years, the sheep utilised ~400 to 600 kg of biomass per hectare from old man saltbush at a planting density of 930 plants per hectare. Each plant therefore produced an average of 430 to 650 g of edible biomass. Each river saltbush plant produced 570 to 800 g of edible biomass. Even in these dense saltbush stands the volunteer under-storey of annual grasses and herbs contributed about the same amount of edible biomass as the saltbush.

However, when wider alleys are left between the saltbush rows to give more opportunity to the under-storey, dry matter production results can be significantly boosted. In such situations, the saltbush will typically contribute only 10 to 30% of the total edible dry matter.

WATER USE

During the late 1990s, anecdotal evidence from farmer experiences began to emerge in Western Australia that saltbush stands were using sufficient water to draw down the watertable. This drawing down of the watertable can have a double barrelled impact. Firstly, by lowering the watertable, saltbush can reduce the amount of salt entering into the root zone of the more shallow-rooted under-storey species. Secondly, drying out the soil profile by lowering the watertable creates a buffer zone that enables winter rain to leach salt out of the surface soil. This makes the site more suitable for productive under-storey species that are less salt tolerant than saltbush.

The extensive research undertaken in the SGSL initiative has provided some support for the farmer experiences. It showed that saltbush can lower the watertable, but was not able to show significant improvements in the soil conditions for under-storey. However, we know from first principles that lowering watertables in summer will decrease the rise of salts into the root zone, and increase the potential for rainfall to leach salts down out of the root zone. It is likely that several years would be needed for this effect to have a measurable impact in the low rainfall zones where saltbush and under-storey is an option.

Flowering clover and other under-storey species in saltbush alleys.

AMENITY AND ENVIRONMENTAL

The amenity value of a well-managed stand of saltbush and under-storey, particularly when compared with bare and untreated saltland, is unmistakeable. Most of the evidence supporting amenity benefits from saltland pastures, including saltbush and under-storey, also comes from farmer experience.[5]

Revegetation with saltbush and under-storey can assist in reducing soil erosion, and can enhance flora and fauna diversity by providing habitat to small local birds, lizards and other small animals. There is some evidence of improved microbial activity in soils established to saltbush compared with bare areas. However all of these potential benefits are also dependent on how the saltland pasture is managed, particularly in terms of the grazing pressure and timing, and on seasonal conditions.[34]

Some of these benefits are assumed, or based on intuition rather than on well-documented research, and the possibility for negative impacts cannot be ignored. For example, establishment of saltland pastures (saltbush-based in WA and perennial grass-based in NSW) led to an increase in salt export from the sites in the first couple of years, caused by the soil disturbance associated with pasture establishment.[34] However, rates of salt export declined to below the untreated control after the saltbush pasture had been properly established and the soil was no longer disturbed.

By far the most consistently reported environmental benefit from establishing saltland pastures (including dense saltbush plantings) is visual amenity. Though not easily measurable, farmers greatly value the improved visual amenity associated with replacing visibly salt affected areas with productive groundcover.

More so than other saltland pasture options, saltbush (either dense plantings, or spaced rows with under-storey) can provide a substantial windbreak. These windbreaks can give increased stock shelter, and there is widespread anecdotal evidence to suggest that such shelter can improve lambing percentages and reduce mortality in off-shears sheep. In addition, in areas prone to wind erosion, saltbush stands can support heavy stocking to the point where most groundcover is removed, but without significantly increasing the erosion risk.

HOW THE $$$s STACK UP

Farmers with saltbush stands report many benefits (such as increased production, enhanced amenity, delayed grazing of other pastures after the autumn break, more land for livestock during the cropping season and out-of-season green pick) but the costs and returns are rarely quantified.

An analysis of farmer trials from the SGSL Producer Network in WA (many of which were based on saltbush and under-storey systems) showed that profitability varies greatly (see Table SS4.1), though 16 of the 21 sites reached break even within 10 years. The monetary value estimates in Table SS4.1 are significantly less than the benefits that farmers report anecdotally, mainly because the non-financial benefits are not included in the economic analysis. Whole farm economic modelling supports the farmers' contention, suggesting that the whole farm benefits are about double the easily identifiable cash benefits.

The profitability of saltbush and under-storey pastures in general is determined by:

- **Infrastructure costs**. If the site requires significant expenditure on site preparation (raised beds, surface water management), fencing or water supply then profitability will be more difficult.
- **Establishment costs.** These are a primary determinant of profitability and in the SGSL data (see Table SS4.1) they varied from $77 to $787/ha. In general, the cost of establishing a saltland pasture are similar to those of a non-saline pasture if sown from seed, but costs will be substantially higher if the pasture is established with nursery-raised saltbush seedlings.
- **Risk of failure.** This is significantly higher than for non-saline pastures because of the salinity and waterlogging. There is also a risk with the under-storey because for the improved species the present levels of tolerance to salinity and waterlogging are not high. With the saltbush, the risk associated with establishing the plants can be significantly reduced by using nursery-raised seedlings, but this increases the establishment costs.
- **Pasture productivity.** In general terms, the lower the rainfall and the saltier the site, the lower the pasture and animal production that can be expected. Given that saltbush and under-storey systems are most suited to the low rainfall zone, the production potential will be lower than for higher rainfall sites and therefore profitability will be dependent on keeping the establishment costs down.
- **Nutritive value.** As saltbush accumulates salt, animals cannot usually eat enough of it to meet their nutritional needs. This is more of a problem in dense saltbush plantings than for saltbush and under-storey. The main nutritional challenge for saltbush and under-storey is that in autumn, the most common time for grazing saltbush-based pastures, the under-storey is dead and has lower nutritive value. The presence of legumes in the under-storey will help maintain nutritive value to some degree;
- **Product prices**. The cost of ongoing inputs and the prices paid for meat and wool products will always affect the economics of any pasture establishment expenditure and saltbush; under-storey systems are no exception.

In summary, from across the SGSL farmer sites, the highest risk of failure and lowest estimates of profitability occurred in the low rainfall areas where saltbush and under-storey are one of the recommended options.[35] However, balancing this is the fact that such land has little opportunity cost and any green feed in autumn has a particularly high value.

A range of farmer case studies can be found on the Saltland Genie website from across southern Australia where saltbush (either dense plantings or saltbush with improved under-storey) has become an integral part of the farm operation. The case studies are dominated by WA and SA examples as this is where the most extensive saltland plantings exist.

Table SS4.1: An analysis of 21 of the WA grower network sites from the SGSL initiative, showing project cost and estimated benefits.[35]

Result	Excluding costs of infrastructure	
	Average	Range
Establishment cost per ha	$324/ha	$77/ha to $787/ha
Payback period*	16 out of 21 sites payback inside 10 years	2 yrs to >20 yrs
Benefit:Cost Ratio (BCR)*	1.64	0.22 to 6.19
Internal Rate of Return (IRR)**	8% (19 sites only)	< -10% to 37%
Net Present Value (NPV)**	+$6,177	-$6,214 to +$54,761
Project Area	26 ha	4 ha to 49 ha

ESTABLISHMENT AND MANAGEMENT

CHOOSING THE RIGHT SPECIES AND VARIETIES

While selecting the right species and varieties can be important, in most situations, farmers establishing saltbush and under-storey will have little practical control.

The three most important saltbush species used in Australia are old man saltbush, river saltbush and wavy leaf saltbush. Mixtures of species are often sown with direct-seeding to reduce the risk of establishment failure. If nursery-raised seedlings are to be planted, the planting of old man saltbush or a mixture of old man and river saltbushes is recommended. Nearly all stands of saltbush are planted from what are essentially wild sources of seed, there having been limited attempts to select germplasm.

Tamlin's Nursery in South Australia currently market a clone of old man saltbush called 'Eyres Green', claimed to have rapid recovery from grazing with good digestibility and high protein.

The under-storey will usually be sown as a shotgun mixture, with different mixtures suited to different regions, so local advice is essential. For lower salinity sites, legumes can be the critical element of the under-storey and the most appropriate species will depend on the salinity levels, with burr medic the most salt-tolerant, and sub-clover the least. Balansa clover (cv. Frontier) has a reputation for soils with low levels of salinity and no waterlogging, however it seems to have a problem with persistence. As the salinity of the site increases, or for the more saline areas within a site, the legumes will decline rapidly in production and persistence, so it is normal practice to include annual grasses (such as Italian ryegrass) in the mix.

ESTABLISHMENT TECHNIQUES

In the saltbush and under-storey system, the saltbush provides the perennial component that can use water over summer and improve the site for under-storey species. This makes the successful establishment of the saltbush critical. The under-storey can be established, or re-established relatively cheaply at a later stage.

There are two ways of establishing the saltbush component of the pasture: niche seeding (growing saltbush directly from seed) and the planting of nursery-raised seedlings with a tree planter. Growing a good stand of saltland is based on the same skills used to other crops and pastures (e.g. good site preparation, weed control, insect control, timing and grazing management). On non-saline land, germination and establishment success is routinely challenged by drought, frost, insect attack, and weed competition. The same occurs on saltland, but with additional risks associated with salinity, waterlogging and inundation.

DIRECT SEEDING OF SALTBUSH

Direct seeding should only be used on soils with low to moderate salinity and a sandy surface soil. It is usually carried out by a contractor with a niche seeder that places the seeds mixed with vermiculite at 2–3 m intervals along the top of a raised M-shaped mound. The raising of the mound reduces waterlogging and the vermiculite acts as a mulch, reducing the movement of salt to the soil surface by capillarity. Contract rates for the seeding operation can be about $150-$200 per hectare.

Method

Spring of the year before planting. The site should be no more than moderately saline (with an EC_e in the subsoil of less than 8 dS/m) with a sandy surface soil. In the year before planting, spray-top with a knockdown herbicide to prevent seed-set by annual grasses. Plan the layout to ensure that the mounds established by the niche seeder will not hold back surface water and any additional surface water management structures are installed. Red-legged earth mite can be *partly* controlled in the spring before sowing by spraying as close as possible to the optimal Timerite®.[36]

Year 1 – sowing the saltbush seeds. Wait until the soil temperatures have warmed and the risk of waterlogging has abated (August-September depending on location and winter rainfall). Apply two knockdown herbicides – glyphosate four weeks before seeding, and SpraySeed® two days before seeding. Cultivate just before niche seeding. After seeding, look carefully for damaging insects as saltbush seedlings are very vulnerable to attack from these insects. Spray **immediately** if red-legged earth mites, aphids or native budworm are present. Check at weekly intervals for 10-15 weeks. More than one spray may be required.

Grazing. A light grazing of the saltbush is usually available in the first autumn after planting.

NURSERY-RAISED SEEDLINGS

Nursery-raised seedlings are more versatile and can be grown on more saline soils and with a wider range of textures than direct seeding. If the site is suited to either method, then there is a trade-off between cost and reliability. Saltbush seedlings are available from a number of nurseries in WA and the eastern States, and are usually planted with a commercial tree planter.

Method

Spring of the year before planting. The site should be no more than moderately saline (to allow for the under-storey), with an EC_e in the subsoil of no more than 8 dS/m. If the planting mounds are established prior to planting, make sure the mounds do not hold back the drainage of surface water. The layout should be designed to assist surface drainage. Red-legged earth mites can be *partly* controlled in the spring of the preparation year by spraying as close as possible to the optimal Timerite® spraying date.[36]

Year 1 – Planting the saltbush. Wait until the risk from waterlogging has abated (August to October depending on location and climate). Apply a knockdown herbicide, cultivate and then plant the saltbushes. Monitor for red-legged earth mite and spray promptly as needed.

Grazing. A light grazing of the saltbush is usually available in the first autumn after planting.

The cost of establishment using nursery-raised seedlings will depend on the price per plant, the density of planting, planting costs (including spraying and cultivation) and any costs associated with the pre-preparation of the site, plus the cost of providing infrastructure like fences and sources of stock water.

ESTABLISHING THE UNDER-STOREY

Establishing the sown under-storey between the saltbush rows is the same process as establishing pastures on other parts of the farm.

Optimal establishment practice includes weed control (in the previous season before seed set and at planting), fertiliser application (soil testing is recommended), consideration of insects, and sowing of quality seed. It is critical to include an appropriate rhizobia with the legume seed because it is unlikely that there will be existing rhizobia in the saline soil where there may not have been any legumes for many years.

In general:

- Weed control with a knockdown spray in spring of the year before sowing as per the establishment of saltbush.
- Spraying for red-legged earth mite as close as possible to the optimal Timerite® spraying date.[36]
- After weeds have germinated following the break of season, apply a knockdown, fertilise and sow.
- Through July and August, check for insects.

Dustin McCreery showing old man saltbush seedlings ready to go from Chatfield's Nursery in Tammin, WA. Photo: J. Hardy

TIMING OF ESTABLISHMENT

The establishment of a saltbush and under-storey pasture is usually a two-stage process. As a warm season grower, saltbush needs to be established (sown, or planted) in spring, while the annual under-storey species need to be established in autumn.

Saltbush. The timing of direct seeding is a tactical choice which must be adapted to the prevailing seasonal conditions. Seeding early can be extremely difficult if the site is wet, with most salty sites wet over winter. Even if the soil is dry enough to sow, there is a risk of failure because of waterlogging damage from subsequent spring rainfall. Germination will be slow from early sowing. River saltbush in particular is very slow to emerge if the average daily temperature is less than 10°C.

These challenges subside as spring advances, waterlogging risk declines and temperatures rise. However, the emerging saltbush seedlings have a greater risk of not being able to establish sufficiently developed root systems to ensure survival as the soil dries out and becomes more saline over summer.

The best time to direct seed will vary with the location (annual rainfall and temperature), site conditions (soil texture, waterlogging) and the current seasonal conditions.

Under-storey. For the under-storey there are essentially two choices – sowing in the autumn prior to saltbush establishment, or sowing in the autumn following saltbush establishment. While both are possible, we tend to recommend sowing the under-storey in the autumn prior to establishing the saltbush because of the following advantages:

- Sowing both the under-storey and the saltbush in the same year minimises both the costs and time involved, so when the saltbush is ready for its first grazing in the autumn after it has been established, there is an under-storey already in place.
- There is less chance of bare soil and concentration of salts in the soil surface if there is an under-storey present over the first summer.
- Weed and insect control in the spring prior, and then in the autumn with the sowing of the under-storey will reduce the weed and insect pressure on the saltbush.
- Sowing rates for the under-storey can be low as the site will not be grazed till the following autumn and the pasture will get a chance to bulk up and set seed.
- Predation (by rabbits and kangaroos) of the saltbush seedlings may be reduced because of the availability of under-storey.
- There is no saltbush to be affected if a knockdown is used prior to sowing the under-storey.
- Large commercial machinery (e.g. air seeders) can be used because the saltbush rows are not yet established.

The downside with sowing the under-storey prior to the saltbush is that it can compete strongly with the saltbush seedlings. This can be managed by either a narrow band of knockdown herbicide along the planting rows for the saltbush if it is to be direct seeded, or by physical control if planting seedlings as most seedling planters scalp the under-storey out of the way.

If the under-storey is sown in the autumn following saltbush establishment, most normal practices for sowing the under-storey pasture can be followed. That is, waiting for germination of the annual weeds, spraying with a knockdown herbicide and then sowing with fertiliser. If possible try to avoid spraying the knockdown herbicide directly over the saltbush rows. However if this in not possible, anecdotal evidence suggests that well-established saltbush can tolerate glyphosate at approximately 1 L/ha without permanent ill-effects. As the saltbush will be quite well established to survive the summer it will not be out-competed by the more actively growing under-storey.

MANAGEMENT NEEDS AND TIPS

Early stages. Newly established saltbush seedlings are quite vulnerable. They are very poor competitors against weeds, and are vulnerable to insect pests and grazing animals (including rabbits and kangaroos). Annual weeds can be controlled by over-spraying well-established saltbush with gyphosate at about 1 L/ha. Once firmly established, little further input is required. Individual old man saltbush plants are very long-lived.

First grazing. Most saltbush planted in early spring will be large and robust enough to graze during the following autumn. This first grazing should be lighter than subsequent grazings, and carefully monitored to ensure stock are removed when there is still significant leaf remaining, and before there is heavy damage to the main branches. This grazing can also reduce the susceptibility of the saltbush plants to herbicide sprays that might be applied if the under-storey is still to be sown.

Fencing. Preventing grazing during establishment is critical. Many farmers can save on a fence at the outset by planting saltland while the rest of the paddock is being cropped. Then the investment in fencing only needs to be made once the level of establishment – and the likely value of the pasture – can be seen.

Pests and diseases. Many saltbushes (not wavy leaf) are native to Australia and therefore have a range of local insects and diseases that eat or attack them. Mostly, pest and disease attacks are episodic and the plants generally recover satisfactorily. Reports of major pest or disease damage are relatively rare, except insect attacks on seedlings (especially by mites, aphids and budworms), which if not controlled, can kill many seedlings.

GRAZING OPTIONS AND GRAZING MANAGEMENT

As with many other aspects of the saltbush and under-storey option, it is the saltbush that requires the more specialised management to ensure its productivity and persistence. Constant heavy grazing will eventually weaken and kill saltbush.

To a large degree, the annual under-storey species behave the same on saltland as they do on other parts of the farm. They are best not grazed while they germinate and establish, they can be rotationally grazed or set stocked at other times, and those legumes that are aerial seeders (such as balansa clover and medics) require some protection from grazing during seed set.

Saltbush and under-storey pastures, like dense saltbush plantings, have been shown to thrive under a grazing management system that involves an annual crash-grazing where the under-storey is entirely consumed and the saltbush is grazed back to the twigs in autumn when other farm feed sources have been exhausted. The saltbush provides protection from wind erosion needed to allow this hard grazing.

There is no advantage in saving saltbush-based pastures for less productive seasons as a living haystack or drought reserve. Old man saltbush drops a lot of leaves when left ungrazed and there is little advantage in deferred grazing between years.[37] In addition, not grazing the saltbush at least annually increases the risk of the plants exceeding sheep grazing height and then preferentially directing future growth to the non-grazed parts of the plant.

ANIMAL NUTRITION ISSUES

The saltbush component of saltbush and under-storey pastures provides a nutritional challenge to livestock because of the high salt concentration in the leaves. As salt in the feed increases, appetite is suppressed, intake is decreased and digestion is disrupted. Research shows clearly that livestock grazing saltbush alone will not get sufficient nutrients for maintenance.[38]

For grazing animals to cope with high levels of salt in the diet they must have access to a large supply of high quality drinking water. If the drinking water also contains salt, then the ability of livestock to eat saltbush is further reduced. In one study, feed intake of sheep on old man saltbush fell by more than half when pure drinking water was replaced by water containing 1% salt.[38]

One of the great advantages of this saltbush and under-storey option is that some of the nutritional challenges associated with the saltbush are overcome by the under-storey. When sheep self select a diet from a saltbush and under-storey pasture, they never select more saltbush than their digestive system can manage. Good quality water is important, but less critical than is the case if animals are grazing dense saltbush plantings where there is little under-storey to balance their diet and reduce their salt intake.

SUPPORTING RESOURCES

Barrett-Lennard, S. *Saltland Pastures in Australia – a practical guide*. Available from http://www.landwaterwool.gov.au/products/pr030563.

Liddicoat, C. and McFarlane, J. (2007). *Saltland Pastures for South Australia*, Department of Water, Land and Biodiversity Conservation Report No 2007/08. This is a product of the SGSL initiative, providing a wealth of information that will be of value beyond SA. It can be or ordered from http://www.landwaterwool.gov.au/products/px071257-0].

Masters, David G., Benes, Sharon E., Norman, Hayley C. (2007). Biosaline agriculture for forage and livestock production. *Agriculture, Ecosystems and Environment* **119**; 234–248.

From 1997 to 2002 the *National Land & Water Resources Audit* significantly progressed the collection and collation of information related to Australia's natural resource management – with a significant focus on dryland salinity. *Australian Dryland Salinity Assessment 2000* can be viewed online at Australian Natural Resources Atlas.

The *National Dryland Salinity Program* (NDSP 1993–2003) was the first national attempt to better understand the causes, impacts, costs and management options for preventing and/or overcoming dryland salinity. The final year of the program was dedicated to harvesting the knowledge and making it available to the diverse range of stakeholders through the *Managing Dryland Salinity in Australia* resource kit. http://www.ndsp.gov.au/. An update was published by Land & Water Australia in 2006 [http://www.lwa.gov.au/].

Tall wheatgrass

IN A NUTSHELL

Tall wheatgrass (*Thinopyrum ponticum*) is a temperate perennial grass which tolerates soils of moderate subsoil salinity (EC_e values of 4–8 dS/m) and moderate waterlogging. It has been widely used as a saltland pasture in south-west Victoria and the upper south-east of South Australia, often in a shotgun mix with puccinellia and balansa and strawberry clovers.

Though a warm season grower, tall wheatgrass is not a subtropical species, and so it is not frost sensitive, making it well suited to southern Victoria and South Australia. Tall wheatgrass can produce significant biomass given sufficient summer moisture. It is strongly tussock forming and can quickly become clumpy, rank and unpalatable to livestock if not well managed. In addition, the clumps or tussocks can become so large as to make a paddock almost untrafficable. If allowed to run up to seed it can spread and colonise areas where it is unwanted, particularly along watercourses.

The two common tall wheatgrass cultivars Dundas and Tyrrell have similar yields and salinity tolerance across a range of saline soils in western Victoria. Dundas is a selection from within Tyrrell for enhanced leafiness and quality. Dundas is the recommended variety for reasons associated with quality for livestock, and minimising the risk of spread as an environmental weed.

Research indicates that mature plants of tall wheatgrass have relatively similar salinity tolerance, but lower waterlogging tolerance, than puccinellia. The lower persistence of tall wheatgrass at waterlogged sites in South Australia supports this theory. However, tall wheatgrass is more persistent and productive at better drained sites.

INDENTIFYING TALL WHEATGRASS

Tall wheatgrass has long, blue-green ribbed leaves that are quite tough and is sometimes mistaken for demeter fescue (which is a darker and glossier green). Tall wheatgrass can send up seed stems to 2 metres and the plants form thick clumps which, if allowed to grow unchecked, can make traffic very difficult. It is often noticeable in late summer as the only green grass on salt affected land.

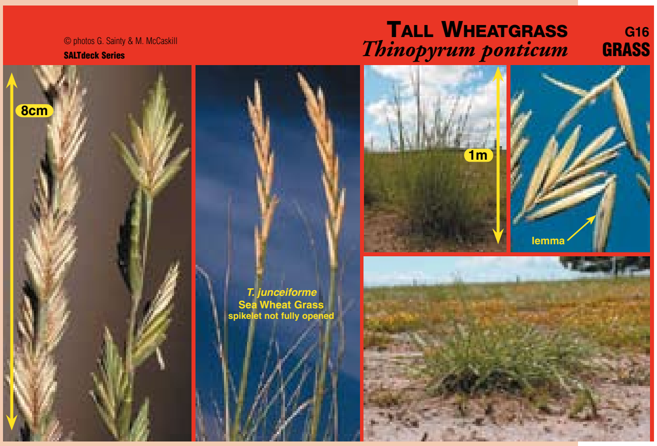


Figure SS5.1: SALTdeck identification card for tall wheatgrass.

MOST LIKELY SITUATIONS

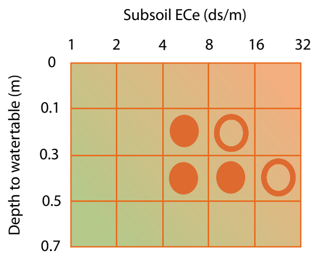
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and where they are likely to thrive. For tall wheatgrass, these factors are summarised below.

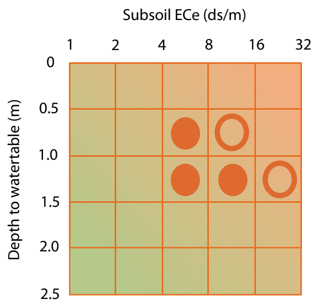
5 – MOST LIKELY SITUATIONS FOR TALL WHEATGRASS PASTURES

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER



SUMMER



DRIVERS OF PLANT ZONATION

- Deeper rooted halophyte
- Damaged by salt/waterlogging interaction in winter
- Less waterlogging tolerant than puccinellia
- Growth in summer assisted by groundwater accessible to roots
- Rainfall 400-700 mm

Key to symbols

- ● *This is the zone most preferred by tall wheatgrass and where it is highly recommended.*
- • *Tall wheatgrass is one of the possible options for this zone, but it is outside its preferred conditions.*
- ○ *Tall wheatgrass will most likely survive in this zone, but its growth will be poor and therefore it is not recommended.*

COMMON INDICATOR SPECIES

Tall wheatgrass thrives in conditions that also favour buck's horn plantain, sea barleygrass and spiny rush. These are conditions characterised by low to moderate subsoil salinity (EC_e 2-8 dS/m measured in summer) and low to moderate waterlogging. Tall wheatgrass is unlikely to be found in saltier environments where samphire dominates, or in areas that have high waterlogging or inundated for extensive periods during the warmer months. SALTdeck cards assist with the identification of the 50 most common saltland species.[39]

SOIL AND CLIMATE REQUIREMENTS

The minimum annual rainfall for tall wheatgrass is reported as about 425 mm, although it is generally regarded as a pasture for higher rainfall zones, up to as much as 800 mm. It is frost tolerant and recovers well after burning. It does not persist in soils that have high waterlogging over spring and into summer, but it does persist in soils subject to low to moderate waterlogging in winter that dry out over summer.

Tall wheatgrass is tolerant of acid and alkaline soils. It grows particularly well in soils of moderate subsoil salinity (EC_e 4-8 dS/m), soils often supporting sea barleygrass and buck's horn plantain. It can tolerate soils in which the salinity of the topsoil reaches summer EC_e values of 20 dS/m, providing it can still access moisture from the subsoil in late spring. Once well established it can tolerate higher surface salinities if it has access to fresher water at depth.

It is not uncommon for farmers to sow a mix of tall wheatgrass and puccinellia, allowing each to find its niche in a saline/waterlogged but nonetheless heterogeneous landscape. While quantitative data on salt and waterlogging tolerance is generally unavailable, CRC Salinity research shows species change from almost 100% tall wheatgrass to 100% puccinellia in response only to changes in the degree of waterlogging.[40]

WATERLOGGING AND SURFACE WATER MANAGEMENT

Tall wheatgrass is tolerant of moderate waterlogging in the cool season and brief periods of inundation, provided some of the plant is above the water level. As noted above, it is less tolerant of waterlogging under saline conditions than puccinellia, and improved surface drainage should improve its growth during periods of excess water.

Surface drainage can also be of value in allowing initial access to the site for establishing the pasture. However, deeper groundwater drains may prove to be a disadvantage to tall wheatgrass, potentially depriving the pasture of moisture from deeper in the soil profile in early summer.[41]

THE BENEFITS

PRODUCTION

In an experiment at Dunkeld, western Victoria, the productivity of tall wheatgrass was affected by soil salinity. Yields of 7 t/ha/yr occurred in soils of moderate subsoil salinity, but these increased to 13 t/ha/yr in soils of low subsoil salinity.

Previously, enquiries from producers in Victoria prompted a pilot feed quality study of 84 samples of tall wheatgrass from nine locations across the south-west to test feed quality at various times of the year. The sites included newly renovated and established pastures including both Tyrrell and Dundas cultivars. Old established sites that had been mismanaged for years and allowed to go rank were included to see if they could be brought back to productivity by grazing or other management.

The results clearly indicated that removing the rank grass and allowing new green growth to regenerate significantly improved pasture quality (digestibility, crude protein and metabolisable energy). While the data were insufficient to show a direct link between the different management techniques and feed value, they strongly indicated that effectively managed tall wheatgrass pastures are more than capable of filling the summer/autumn feed gap, while most other pastures are dormant or dead.

The best managed tall wheatgrass sites had crude protein and energy levels similar to perennial ryegrass and tall fescue but quality declined rapidly as tall wheatgrass grew rank and went to head (see Table SS5.1).

The tall wheatgrass declined in quality over late summer even when kept short and green, however by then it was the only green pasture available on farm. The researchers concluded that, for the region studied, tall wheatgrass is the most successful perennial grass species that can be grown in moderately saline soils. It offers the added potential benefit of being an alternative pasture in areas where ryegrass staggers and phalaris toxicity are problems in early autumn.[42]

Table SS5.1: Mean feed quality results for spring 2002.

Species	CP (Protein) %	Digestibility %	ME (Energy MJ/kg)
Tall fescue	20.0	74.5	11.2
Perennial ryegrass	21.2	77.3	11.3
Annual ryegrass	13.2	70.6	10.3
Phalaris	14.3	74.9	11.0
Mixed pasture	19.3	72.7	10.6
Tall wheatgrass (< 20 cm)	18.9	75.3	11.0
Tall wheatgrass (>20 cm)	15.2	66.4	9.6
Tall wheatgrass (>1 m)	7.6	52.4	7.4

A clear message from all the work on wheatgrass pastures is that they must be kept short and vegetative. This management rule also assists with the persistence of any complementary legumes in the pasture.

How the short pasture is achieved is not really important, although clearly hard grazing is the best use of the resource. Old rank tall wheatgrass also responds to slashing, burning or mulching of old growth, however working in old neglected wheatgrass paddocks can be hard on machinery.

The ability of tall wheatgrass to locally lower the saline watertable can provide a more hospitable environment for companion legumes such as balansa or strawberry clover. When effectively managed, tall wheatgrass pastures sown with a companion legume are capable of increasing stocking rates from 0.5 DSE/ha to 12 DSE/ha.

Research at four non-saline sites in the upper south-east of SA from 2002 to 2005 compared the herbage produced by 17 different perennial grasses including tall wheatgrass. Despite displaying good persistence throughout the trial period, Dundas tall wheatgrass was consistently outperformed by other species. In addition, the spring crude protein and energy content of Dundas was lower than that of all other grasses. This appears to suggest that this cultivar is best suited to environments where its relative ability to tolerate moderate soil salinity and moderate waterlogging can be exploited.[42]

Farmer case studies[42] indicate that tall wheatgrass pastures can be used to make good silage, although the rapid decline in pasture quality with plant maturity suggests that it is more difficult to produce good hay.

WATER USE

Tall wheatgrass can reduce topsoil salinity, firstly by preventing the capillary rise of salts to the surface, and secondly by drying out the soil which then allows rainfall to wash salts deeper into the profile.

The ability of tall wheatgrass to use soil water throughout summer means that the soil will be drier in autumn and will need more rainfall to become saturated following the autumn break. This delays the onset of winter waterlogging under tall wheatgrass pastures (which may include other species such as balansa clover or puccinellia). Monitoring of a site in the Great Southern Region, WA, showed that winter waterlogging occurred a month later on tall wheatgrass-balansa pasture compared to balansa-only pasture. The duration of waterlogging on tall wheatgrass-balansa pastures was also reduced to a third of the time of the balansa-only pasture during a growing season (May – October).

Pasture production is generally reduced under waterlogged conditions, so the summer water use by tall wheatgrass has a further benefit beyond its own direct contribution to productivity, by providing a more suitable environment for less waterlogging tolerant pasture species.

AMENITY AND ENVIRONMENTAL

Improved visual amenity is a strong motivator for many farmers revegetating saltland. Under suitable conditions (moderate salinity and waterlogging), tall wheatgrass can transform a salt-affected site otherwise supporting only sparse sea barleygrass.

Tall wheatgrass should not be used where grazing pressure is insufficient to control its spread by seed into non-target areas.

In terms of biodiversity value, the SGSL initiative showed that tall wheatgrass-based pastures are intermediate between bare salt scalds and remnant native vegetation as measured by Landscape Functional Analysis. They represent better production and environmental outcomes than untreated saline areas.

HOW THE $$$s STACK UP

The widespread use of tall wheatgrass throughout south-west Victoria and the upper south-east of SA does not give a strong indication of the profitability of this pasture. For many graziers the main issue has become how to get rid of poorly managed wheatgrass (usually Tyrrell) rather than how to encourage it to persist. The value of tall wheatgrass, particularly its economic value, is critically dependent on the management practices that support it.

As a rule, the grazing benefit from tall wheatgrass is principally that it allows graziers to maintain more stock per hectare rather than to finish stock for market.

A range of farmer case studies can be found on the Saltland Genie website.[43]

Whole farm modelling to determine the economic value of forage produced from salt-tolerant perennial pastures has been conducted for a number of different regions of Western Australia, south-west Victoria and the slopes of New South Wales.[43] As an example, converting saltland in Victoria to a tall wheatgrass gave a benefit of $265/ha for a Class 1 site and and158/ha for a class 2 site.

ESTABLISHMENT AND MANAGEMENT

Until 2000, Tyrrell was the only variety available in Australia. The cultivar Dundas was released in 2000, developed from Tyrrell and two US varieties by selecting plants with improved forage quality and increased growth rate. Dundas is now generally regarded as the variety of choice, except where farmers are harvesting their own seed from old Tyrrell stands.

It is not uncommon to sow puccinellia with tall wheatgrass, however they tend to occupy somewhat different landscape zones, so that it might be more economical to assess the site carefully and use the species mix only where these zones are likely to overlap.

Companion legumes are necessary to ensure the pasture's continued vigour. Balansa and Persian clover are both annual clovers that are generally compatible with tall wheatgrass. These persist in areas of low salinity, balansa being particularly adapted to waterlogging, but they tend not to regenerate in soils of moderate salinity. They should be direct-drilled the year after the tall wheatgrass is established, to ensure that the perennial has established well. Strawberry clover is a perennial legume that should be sown with tall wheatgrass (see Saltland Solution 10 – Legumes for saltland).

SITE PREPARATION

It is best to fence to control grazing as tall wheatgrass does not make strong early growth, and is often sown into soil that soon becomes very wet and vulnerable to pugging by livestock. Temporary electric fencing may be sufficient, particularly for small areas where separate grazing is impractical.

If waterlogging is likely to present a problem at sowing, shallow drains can be used to remove excess water. Diversion or reverse interceptor banks will reduce the movement of runoff water onto the area, but care should be taken that these banks do not go through sodic soil that might give way and lead to erosion. When designing drainage systems it is important (and possibly a legal requirement) to consider the impact of water disposal on downstream biodiversity and on other landholders, and ensure that no harm will be done.

It is important to control weeds, especially annual grasses, most often sea barleygrass, by spray topping the previous spring. It may still be necessary to kill germinating weeds prior to sowing with a knockdown herbicide because germinating annuals will easily out-compete tall wheatgrass seedlings.

Sheep graze a new tall wheatgrass pasture. Photo: R. Zollinger

The soil should be lightly cultivated or scarified prior to the break of the season. The time without vegetation should be minimised to reduce the capillary rise of salts to the surface.

WEED AND PEST CONTROL

The main weeds are capeweed and annual grasses such as sea barleygrass, which should be sprayed in the spring before sowing to reduce the seedbank. Tall wheatgrass should not be sown with annual legumes, because the vigour of the annuals will suppress the growth of the tall wheatgrass seedlings, particularly on areas of low salinity. Buck's horn plantain and summer-growing salt-tolerant perennial grasses do not represent strong competition for tall wheatgrass, and are useful within a tall wheatgrass-based pasture. A full kill of these species is not necessary to establish tall wheatgrass.

Red-legged earth mite (RLEM) can challenge wheatgrass during establishment. The Timerite® program[44] is an excellent tool for controlling RLEM, but timely chemical application can be difficult on very wet sites.

SOWING

Pasture mixes

Single species pastures are the easiest to manage, and since the productivity from tall wheatgrass is very management dependent, this is an important consideration.

Companion species can include puccinellia, balansa clover, strawberry clover, persian clover, tall fescue and lucerne, depending on site salinity, waterlogging, average rainfall and other site conditions. The grasses help to balance the pasture by extending the grazing season and taking advantage of variations in soil condition across the paddock. The legumes contribute valuable fixed nitrogen to the grasses and protein to the grazing animals.

Typical recommended mixes include:

- EC_e: <5 dS/m: TWG, tall fescue*, strawberry and balansa clovers**.
- EC_e: 5-10 dS/m: TWG, strawberry and balansa clovers.
- EC_e: 10-20 dS/m: TWG and puccinellia.

** Victorian trials have shown that Resolute and Advance tall fescue will germinate and grow at EC_e levels up to approximately 8 dS/m, losing up to 50% of productivity at this higher salinity level.*

*** The early-flowering Frontier balansa has the advantage that it can set seed before salinity levels escalate in spring.*

Under favourable conditions legumes (particularly balansa clover) will out-compete young tall wheatgrass seedlings, particularly when sowing after an opening rain has flushed some salt from the topsoil. Balansa clover is not particularly salt-tolerant and this initial flushing of salt greatly enhances its dominance.[45] Therefore, under conditions of low salinity, balansa clover should not be sown with tall wheatgrass in the first year, but rather a year or two later.

When sown in a mix, some species may colonise different zones. For example, tall wheatgrass or puccinellia will be quite distinctly favoured by local salinity or waterlogging conditions, so considerable expense can be avoided if these conditions are anticipated and the most appropriate species sown.

A tall wheatgrass/puccinellia mix poses significant grazing management compromises. Tall wheatgrass should be grazed heavily over spring and summer to prevent clumpiness, puccinellia is best left standing over this period and then grazed down in autumn.

Seeding rates

Tall wheatgrass is usually sown at 15-20 kg/ha if sown alone as a single species pasture. The seed loses viability rapidly after two years, and in any event seed germination tests are strongly recommended. Germination of 50-90% should be expected for viable seed and sowing rates should reflect this.

The higher the seeding rate, the stronger the stand, but beyond a certain rate the cost will outweigh the benefit.

The following rates are recommended for tall wheatgrass in typical pasture mixes:

- Use 10-15 kg/ha with puccinellia at 4-10 kg/ha.
- Use 4-5 kg/ha in a shot-gun mixture with other grasses or legumes which together might be medics 2 kg/ha, clovers 0.5-2 kg/ha, lucerne 2 kg/ha, phalaris 2 kg/ha.

If legumes are to be sown the year following the tall wheatgrass, the latter should be sown at the lower rate suggested for mixed species. However, this can lead to weed invasion while the grass is thickening up.

Fertilisers and downtime

As with all new pastures, a soil test is advisable. Like most grasses, tall wheatgrass responds to phosphorus and nitrogen, but where other grasses typically get their N from companion legumes this opportunity is not always available to tall wheatgrass in saline conditions. Nitrogen applied in late winter or early spring will boost productivity and maintain plant palatability.

Establishment costs are about $300/ha for seed, cultivation, herbicide and fertiliser, plus a further cost for fencing which will depend very much on the size of the saline area. In addition there is the opportunity cost associated with the establishment downtime, but in most cases the opportunity foregone on unimproved saltland is very small.

Time of sowing

As with all pastures, but perhaps more so on saltland, options for sowing times are largely dependent on weather condition and the state of the paddock. These options come down to:

- Autumn sowing after the autumn break (in southern Victoria this should be before the end of April).
- Dry sowing in April if the autumn break is late (this may lead to excessive weeds).
- Spring sowing, as soon as the area is trafficable after the end of winter. This option works well in years with dry winters and extended springs, but if the area is not trafficable until late spring, there will be insufficient time for the plants to establish before the onset of higher salinity levels in summer. Sowing in spring is of course not an option if an annual such as balansa clover is to be included.[45]

GENERAL PRINCIPLES

Management of tall wheatgrass can mean the difference between having a productive pasture contributing significantly to a grazing enterprise, and having a troublesome paddock of tussocky unpalatable grass. Starting from the point of establishment, managing tall wheatgrass should be seen in two phases

- the year of establishment; and
- subsequent years.

MANAGING NEW STANDS: YEAR 1

The year of establishment is critical for tall wheatgrass as it is not a vigorous seedling, but it does persist well once established. It will respond to nitrogen and phosphorus in spring, although N might not be economical if the pasture is to be only lightly grazed and if growing with a legume.

Careful grazing is essential in the first year to maintain leafiness and allow seed set and thickening of the pasture.

Sites with low salinity

(summer subsoil EC_e values 2-4 dS/m)

Tall wheatgrass can be grazed lightly in spring provided the site is not waterlogged and the seedlings are firmly anchored in the soil.

The vigour of Balansa clover may suppress the grass in the first year. However, if balansa is sown, stock should be removed in time to allow the clover to flower and set seed during spring. Generally, some tall wheatgrass seed set should be allowed in that first year to enable the grass to thicken up.

Grazing over summer-autumn should be conservative, aimed mainly at strengthening a permanent pasture rather than maximising immediate production. Grazing down to about 5 cm will promote strong root development and removing thatch will provide good conditions for regeneration of clover with opening rains.

Sites with moderate salinity

(summer subsoil EC_e values 4-8 dS/m)

Grazing on these sites might not be possible in the first year without damaging the poorly established grass and causing soil damage. Puccinellia, if sown in a pasture mix, will usually also benefit from a first year spell on such sites.

MANAGING NEW STANDS: YEAR 2+

A soil test every 3-5 years will help determine fertiliser needs, but this also should be balanced against cost-effectiveness and the purpose to which the pasture is put.

Where legumes do not persist, usually as a result of saline conditions, wheatgrass will benefit from annual applications of nitrogen with rates of 25-50 kg N/ha. To maintain productivity, up to 9 kg P/ha (in high rainfall areas) might be needed annually. It is important to note that tall wheatgrass will show limited response to N if exchangeable P levels are below a critical level. This value has not been determined for tall wheatgrass, but for many perennial grasses the critical level is approximately 12-14 mg/kg (Olsen P) or 24-28 mg/kg (Colwell P).

Grazing management of mixed pastures containing tall wheatgrass will need to be carefully considered where pasture species have different seasonal activities. Allowing seed set for legumes while controlling the same for tall wheatgrass involves compromises which can cause deterioration of the pasture.

Winter to early-spring grazing in non-waterlogged sites will make use of other components of the pasture mix such as balansa clover. At the first sign of balansa flowering, careful (rather than crash) grazing of the pasture is needed to ensure adequate seed set and retention of the legume base. Experience in the south-east of SA shows that moderate stocking rates during flowering (which also corresponds to a period of high growth) enables adequate seed set and regeneration. However, the pasture composition should be monitored and where the legume component is not regenerating it may be necessary the next year to further limit or stop grazing from flowering until seed set is complete.

Once balansa clover seed set is complete (which depends on the cultivar) the stand can be crash grazed to remove excess balansa growth and wheatgrass stems which will have started to run up to flower.

Continue grazing throughout summer and into autumn to maintain a pasture height below 10 cm. Stock will avoid grass that has begun to go rank, exacerbating the problem of selective grazing, in which case it might be necessary to increase the stocking rate or set up electric fences to force grazing. These mature stands can be profitably harvested for seed.[46]

REJUVENATING OLD TALL WHEATGRASS STANDS

Left unmanaged or poorly grazed, tall wheatgrass reverts to an unproductive monoculture of erect clumps up to 2 m high. There is little grazing value in these stands, it is very difficult to traverse the land, and there is a risk of spreading seed to areas where the tall wheatgrass is unwanted. However these stands can be returned to production and the weed threat can be managed.

Mulching is the ideal technique, breaking stems into smaller segments to allow for quicker breakdown of trash, but this requires specialist mulching machinery which is not always available. Slashing (to a height of 10 cm) is often more achievable, but leaves a heavier mat, which takes longer to break down and tends to smother the pasture regrowth. Burning is also effective in removing all old growth.

After the initial intervention grazing and management should then follow recommendations for managing new stands (year 2+).

Most old stands have no legume component which is critical for a good quality pasture. Where salinity levels allow, balansa clover seed can be broadcast with the fertiliser in early autumn. If soil conditions permit, and if rank grass is removed and some bare ground is visible between plants, balansa clover will readily germinate.

Rank wheatgrass might be okay for brolgas, but not for grazing.
Photo: R. Zollinger

CONTROLLING WEED ESCAPE

Invasiveness or spreading of tall wheatgrass from a planted site is a potential risk. However, studies of 60 tall wheatgrass field sites in the Glenelg Hopkins catchment, south-west Victoria, found little or no spread from the majority of those sites. Across the study sites, there was spread from the original sown area only when sites were allowed to routinely set seed (essentially, ungrazed sites).

The study found that preventing seed set, usually by grazing down to 10 cm in summer-autumn, was the key to controlling the spread from the sown site. This implies that tall wheatgrass pastures should be fenced and contain their own water supply, so as to enable effective grazing management. Also, there should be sufficient distance from the sown site to creeks and waterways, remnant vegetation, plantations and roadsides.

SUPPORTING RESOURCES

Barrett-Lennard, Ed. *Saltland Pastures in Australia – a practical guide.* Available from http://www.landwaterwool.gov.au/products/pr030563.

Liddicoat, C. and McFarlane, J. (2007) *Saltland Pastures for South Australia*, Department of Water, Land and Biodiversity Conservation Report No 2007/08. This is a product of the SGSL initiative, providing a wealth of information that will be of value beyond SA. It can be ordered from http://www.landwaterwool.gov.au/products/px071257-0.

Saltland Solution 6

Puccinellia-based pastures

IN A NUTSHELL

Puccinellia (*Puccinellia ciliata*) is a perennial grass that is highly salt- and waterlogging-tolerant. It is typically sold as the varieties Menemen or Restora Sweet Grass. Along with Distichlis and marine couch, it is the most salt-tolerant of the commercially available grasses and the only salt-tolerant grass suitable for highly saline scalds. Although a perennial species, it behaves like an annual by dying off back to the base when the surface soil dries out in summer. It is best suited to areas with more than 400 mm annual rainfall and where the watertable is not too deep over summer.

Puccinellia is highly palatable and has a low salt concentration in the leaves. It forms tussocks up to 40 cm high and wide and has long, thin leaves. Its growing points are embedded in the base of the plant, which is compact and resistant to grazing.

The plants grow from mid autumn to spring and mature (hay off) in November/December, remaining dormant over summer to early autumn. It has its highest grazing value in winter and spring while green and before flowering. Nutritive value declines as the plant flowers, matures and senesces, and further declines through summer and autumn even though it is still palatable.

It changes from a high-quality, highly digestible feed capable of supporting high animal liveweight gains in spring to less than a maintenance ration in late summer/autumn.

Mature stands can be grazed after the opening rains (when they rapidly produce green feed) and/or more commonly as dry feed in late summer-autumn, although at this stage some supplementation will be needed unless weight loss in the animals is acceptable. Leaving the feed standing over summer shades the soil, reducing the concentration of salts at the soil surface through evaporation.

Puccinellia provides a beneficial food option to sheep producers on saltland, in most instances providing a pasture sward free of grass seeds. Some landholders also successfully harvest puccinellia seed in summer to autumn either for sale or their own on-farm use.

INDENTIFYING PUCCINELLIA

Puccinellia is a fine leafed perennial grass. Although a perennial, in many saltland situations puccinellia hays off completely after flowering in spring as the surface soil dries out and the salt concentration builds up at the soil surface. It can then re-shoot very quickly even prior to the opening rains in autumn[47] in response to cooler temperature and dew.

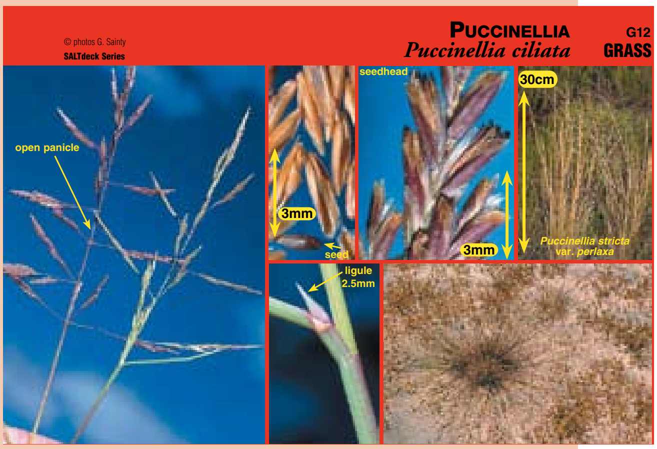


Figure SS6.1: SALTdeck identification card for puccinellia.

MOST LIKELY SITUATIONS

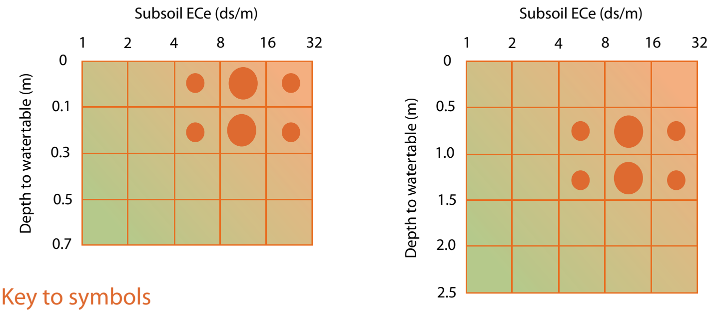
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and where they are likely to thrive. For puccinellia, these factors are summarised below.

6 – MOST LIKELY SITUATIONS FOR PUCCINELLIA-BASED PASTURES

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER | **SUMMER**



DRIVERS OF PLANT ZONATION

- A halophyte so does best with some salinity
- Very tolerant of waterlogging and can survive significant periods of winter inundation
- Winter grower, so cold tolerant
- Acts like an annual by 'dying off' over summer to avoid highest salinity levels
- Rainfall 400+ mm

Key to symbols

● (large) *This is the zone most preferred by puccinellia and where it is highly recommended.*

● (small) *Puccinellia is one of the possible options for this zone, but it is outside its preferred conditions.*

COMMON INDICATOR SPECIES

Puccinellia is highly salt- and waterlogging-tolerant and is relatively non-competitive outside that zone. Therefore, the common indicators for the puccinellia zone are sea barleygrass, curly ryegrass, beardgrass and samphire.[48] There may also be patchy scalding across a site suitable for puccinellia.

SOIL AND CLIMATIC REQUIREMENTS

Puccinellia is a perennial grass that is highly salt-tolerant. It is the most salt-tolerant of the perennial grasses (along with marine couch and Distichlis). It is unique in both being highly waterlogging tolerant and able to withstand very dry summer conditions.

Puccinellia can withstand high salinities (EC_e values) in the surface soil (0-10 cm) in summer up to 50 dS/m. Often, puccinellia sites are highly waterlogged over winter and during that time, surface soil salinities can be far lower. It is this lower winter salinity that makes balansa clover a potential partner in puccinellia-based pastures. However, at this stage, both farmer experience and research results show that balansa will perform strongly in the year of sowing but will not persist. Pasture researchers believe that high surface soil conditions during germination is the main cause of decline in balansa clover with time on saltland. Given this and the importance of balansa in the feed mix, we suggest that the puccinellia/balansa system be focused onto waterlogged saltland with EC_e values less than 16 dS/m.

Although it will tolerate a fairly wide range of soil pH values, it seems that puccinellia is particularly suited to alkaline or highly alkaline soils, or that it has a stronger competitive ability at those higher pH values. There is little scientific evidence to support this, but the fact that puccinellia-based pastures seem to perform strongly on the limestone-based soils of the Upper South East of SA is strong circumstantial evidence.

Puccinellia is only recommended in the higher rainfall zones >400 mm across southern Australia.

It is substantially more waterlogging-tolerant than saltbush, and more salt-tolerant under waterlogged conditions than tall wheatgrass.

WATERLOGGING AND SURFACE WATER MANAGEMENT

Puccinellia is tolerant to prolonged periods of winter-spring inundation (more than three months) as long as the plants are 'tall' enough to stay at least partially out of the water. Some landholders report that puccinellia actually benefits from extended flooding, provided plants are not totally submerged and surface water does not stagnate.

Puccinellia has three important adaptive traits that enable it to grow in saline waterlogged conditions:

- formation of aerenchyma – hollow channels in the roots that enable oxygen to diffuse down the inside of the root and therefore prevent oxygen starvation in the roots;
- formation of a barrier in the roots that reduces the rate at which oxygen leaks out of the aerenchyma into the surrounding soil; and
- arrangement of root cells in a way that maximises the gas-filled spaces between the cells.

Puccinellia growing in a waterlogged area. Photo: Nick Edwards

THE BENEFITS

PRODUCTION

Puccinellia can be grazed in a number of ways, depending on the characteristics of the site and pasture system, seasonal conditions and other feed available on-farm. Most economic benefit is usually gained if puccinellia is used to fill the late summer-autumn feed gap reducing the reliance on expensive supplementary feeding.

While feed quality declines as the plant dries off over the summer period, it still compares favourably with other dry pasture feeds through the summer-autumn period when feed is scarce. However, some supplementation may be required (see 'Animal nutrition issues', page 82), although the puccinellia remains palatable to livestock over summer/autumn when it consists of dead standing material.

Puccinellia plants shoot vigorously following the opening rains, and the feed quality of puccinellia is highest through winter to late spring. However, utilising puccinellia-based pastures during this time can be problematic given that waterlogging and inundation will be features of the site if puccinellia is a major component of the pasture. Grazing on saltland requires flexibility so that animals are not forced to graze (and therefore potentially damage) waterlogged or inundated pastures. Pugging a site by having animals walking across it is a major cause of damage to soil structure.

Where winter flooding is likely, puccinellia should be grazed sparingly early in the season, to ensure plant shoots can remain above water. During this winter period, stock are better grazed on higher ground, retaining the puccinellia pastures for summer-autumn.

Puccinellia stands commonly support 5 DSE/ha. With appropriate management and fertiliser application (including nitrogen), dry matter yields can be doubled and stocking rates of 6-8 DSE/ha supported. At these stocking rates liveweight gains of more than 120 kg/ha and clean fleece weights of more than 20 kg/ha can be achieved.[49]

WATER USE

Puccinellia pastures use almost no water over the summer period because they senesce after flowering and seed set in spring, and do not resume growth until the autumn break. If water use is one of the objectives behind establishing a saltland pasture, then puccinellia is not a suitable option. Unlike puccinellia, tall wheatgrass will use water in summer, however for this option to work, the site needs to be somewhat less waterlogged and less saline than the upper limit for puccinellia.

AMENITY AND ENVIRONMENTAL

Improvement in visual amenity is a strong driving force behind many farmers revegetating saltland. Under suitable conditions (high salinity and waterlogging), puccinellia will transform the visual affront of bare scalded areas into productive pastures with a high degree of groundcover.

As well as visual improvement, puccinellia-based pastures can significantly slow the build up of salts in the surface soil. Leaving the dry puccinellia-based pasture standing over summer, shades the soil and reduces evaporation from the soil surface, thereby reducing the concentration of salts at the soil surface.

In terms of biodiversity value puccinellia-based pastures are intermediate between bare salt scalds and remnant native vegetation as measured by Landscape Functional Analysis, and therefore represent a 'win:win' situation, with better production and environmental outcomes compared to untreated saline areas.[50]

Arjen Ryder and others viewing SGSL Producer Network puccinellia trial.

Photo: Justin Hardy

HOW THE $$$s STACK UP

A major research project examining the productivity and profitability of puccinellia-based pastures was carried out in the Upper South East of SA as part of the Sustainable Grazing on Saline Land (SGSL) program. The research project focused on comparing unimproved saltland with puccinellia-based pastures, and then on further improving puccinellia-based pastures by introducing balansa clover or by applying nitrogen fertiliser. The SGSL research confirmed the suitability and productivity of puccinellia-based pastures for the moderately/highly saline, waterlogging-prone areas of the Upper South East of SA. These benefits are due to a combination of the increased pasture growth and improved nutritive value relative to the previous sea barleygrass-dominant pasture base.

The research project showed that sowing puccinellia pastures increased the maintenance carrying capacity of saltland from an initial 2.4 DSE/ha to 6.7 DSE/ha. A multi-year gross margin model was used to determine profitability of pasture production systems operating a self-replacing wool flock. Establishment cost for puccinellia pastures was estimated at $175/ha, with the greater stocking rate resulting in an $86/ha improvement in wool enterprise gross margin per year. Thus, at the research sites, the investment in pasture improvement paid for itself within two years. With an expected lifespan of at least 10 years, the annual rate of return on capital invested in pasture renovation was calculated at 47% per year.

Puccinellia-based pastures are probably the most widely adopted saltland pasture system in Australia – there are at least 200,000 ha of puccinellia-based pastures in the Upper South East of SA.[50]

ESTABLISHMENT AND MANAGEMENT

CHOOSING THE RIGHT SPECIES AND VARIETIES

The major decision for a puccinellia pasture is whether to make puccinellia the only species, to include a legume with the puccinellia, or to sow puccinellia as one component of a shot-gun mix. There is currently only Menemen or Restora Sweet Grass puccinellia from which to choose – but in fact they are essentially the same plant.

Oversowing puccinellia with a legume such as balansa clover or burr medic has been shown to be very successful but persistence of the clover can be a real limitation depending on salinity and the management of the puccinellia pasture.

WEED CONTROL

Weed control is the most critical factor underpinning successful establishment of puccinellia-based pastures. Sea barleygrass is a major indicator species for where puccinellia will grow well and can tolerate the high levels of waterlogging often associated with 'puccinellia suitable' sites. Where puccinellia is established on sites where sea barleygrass is present, it is essential that this weed be controlled, otherwise it will out-compete the small and relatively slow-growing puccinellia seedlings.

For controlling aggressive weeds such as sea barleygrass, it is recommended that weeds are hit twice. A spray-top in the spring prior to the year of seeding is essential to reduce the weed seedbank in the autumn when puccinellia will be sown. In addition, a knockdown herbicide at the break of the season to remove the first germination of sea barleygrass (and any other weeds) will assist in reducing the competition faced by the emerging puccinellia. Other weed control options include burning and cultivation, or a combination of chemical and mechanical methods. The bottom line is that without thorough weed control, successful establishment of a puccinellia pasture is unlikely.

PEST CONTROL

Red-legged earth mite (RLEM) can severely damage puccinellia seedlings, so monitoring and control during establishment is important. The Timerite® program[51] is an excellent tool for managing RLEM.

SITE PREPARATION

Pre-preparation

Grazing control is essential because establishing puccinellia plants are highly palatable so they are selectively grazed and are easily pulled out by sheep. Fencing also prevents sheep camping on the cooler, salt-affected ground in summer. In some instances permanent fencing may not be appropriate (e.g. if saltland is in small areas and/or is managed as part of a larger paddock). Temporary electric fencing may be an option. Alternatively, it may be convenient to renovate or crop the higher ground in that paddock in the same year with stock excluded from the larger paddock.

If waterlogging is a problem that is likely to prevent effective access for pasture establishment (there is no problem with waterlogging once the puccinellia is established), shallow drains can be used to remove excess water. Diversion banks will reduce the movement of runoff water onto the area. Legal consideration and the disposal of any drainage water (and impacts on downstream biodiversity and landholders) should be considered prior to any drainage action.

Cultivation

Cultivate in early autumn (February/March, excepting sandy soils in low rainfall areas which should not be cultivated until after the break of season due to the risk of wind erosion), leaving a ridged or rough seedbed. A rough seedbed is particularly important for heavier soils or high salinities because it:

- allows opening rains to leach accumulated salts out of the soil surface;
- prevents opening rains flattening the soil surface and creating a surface seal which impedes plant emergence;
- reduces the incidence of sand blasting which can destroy young establishing puccinellia plants;
- provides a buffer against waterlogging and salt on the slightly higher ground; and
- creates a range of niches in which surface seed can lodge.

On sandier or moderately saline ground a high level of ridging or roughness is less crucial, although it can be of benefit on non-wetting sands.

SOWING

Seed should be dropped onto the soil surface, or sown at a very shallow depth. This can be done with a small seeds box or the seed can be mixed with superphosphate (up to 100 kg/ha of superphosphate) just before seeding and sown through the fertiliser box.

Avoid harrowing, particularly on heavy soils or high salinity sites. Trial work has shown up to a threefold depression in dry matter production in the first year of establishment if the seed is covered using trailing harrows.

On clayey soils – leave rough to assist in leaching of salt.

On sandier soils – a light rolling post-seeding is beneficial for germination and establishment, through better seed-soil contact and moisture retention, but should be avoided where prolonged waterlogging is likely.

Seek local advice to see what has worked in your area.

Seeding rate

Sow at 4 to 10 kg/ha. Use the higher rate when sown alone, particularly where salinity is more severe, or where the influx of weeds is likely to be an issue. As a general rule, denser pastures will yield higher productivity and so the higher seeding rates can produce a stronger stand. In a pasture mix, 4 kg/ha is a more usual rate.

From seed germination tests a small but significant percentage of seed may not germinate but can still be viable. This is classified as 'fresh ungerminated seed' and requires a period of extended flooding to germinate. Anecdotally, landholders in the Upper South East of SA consider fresh ungerminated seed an essential and valuable component of the seed bank because of its survival qualities. This seed survives through false breaks and can germinate after long flooding events.

Fertiliser at establishment

Puccinellia will benefit from phosphorus applications if phosphorus levels are below 12 mg/kg (Colwell P). Soil extractable phosphorus levels above this are adequate for puccinellia. Phosphorus requirements will be higher (>20 mg/kg Colwell P) if there is an intention to sow balansa clover on the site.

Consideration should be given to the inclusion of companion legumes wherever site conditions (salinity and waterlogging) allow, to reduce the requirement for subsequent nitrogen fertiliser application.

Nitrogen can be applied at seeding time but higher applications may largely dissipate before the nitrogen can be used by the slow-germinating puccinellia. Plant emergence can take as long as two months on bare saline scalds. However, on more fertile sites nitrogen can boost growth and provide the advantage of earlier grazing.

Whenever nitrogen is applied, the timing and risk of waterlogging are critical to success. Nitrogen may be lost through the bacterially-mediated process of denitrification if waterlogging occurs soon after application. The use of MAP or DAP at seeding can be considered as a means of applying both nitrogen and phosphorus concurrently.

Economic analysis during the SGSL program showed the nitrogen fertiliser was only marginally economic when applied to puccinellia-based pastures on small plots with high fertiliser prices.

Timing of sowing

General advice is to sow in autumn as soon as possible after the opening rains have stimulated the first germination of weed seeds at the site.

In addition, the opening rains will usually leach some of the accumulated salt out of the soil surface making the site more suitable for puccinellia seedlings. Where sea barleygrass is likely to be present, it is essential to wait for germination of the weed seeds then spray and sow the puccinellia. Timeliness is critical and can make a big difference to the success of pasture establishment.

If the site is likely to quickly become untrafficable after opening rains, dry sowing may need to be considered but in this situation, any weeds will emerge at the same time (or more quickly) than the puccinellia and out-compete the pasture. The general recommendation is for spray topping in the spring before sowing, but success with dry sowing can be improved by preventing weed seed set in the previous two springs so as to minimise the number of weed seeds available to germinate with the opening rains.

In higher rainfall areas (above 475 mm) sowing in late winter to early spring has given promising results but relies on good or extended subsequent spring rainfall to allow the germinating puccinellia sufficient time to reach sufficient size to survive the hostile summer conditions. In areas of lower rainfall, if opening rains have not come by early June, delay sowing until the next year. In most years, puccinellia sown after this time does not successfully establish.

Establishment downtime

Puccinellia seedlings are small, relatively slow-growing, highly palatable and susceptible to being pulled out by sheep. Therefore, it is best not set stock until the end of the second growth season after establishment (about 18 months) to allow plants to properly establish, particularly if a lower seeding rate has been used. While it is preferable not to graze during this establishment phase, careful strategic grazing may be possible. Seedlings of puccinellia look very fine and small, but stands will thicken in subsequent years if allowed to set further seed over the first summer. Where soil fertility is high and where higher seeding rates are used and/or pastures thicken up (and reseeding in the second year is less critical), early light grazing may be an option.

BENEFITS FROM FERTILISERS AND COMPANION LEGUMES

The application of fertiliser to puccinellia pastures is one of the key management strategies to increase productivity. Puccinellia will benefit from phosphorus applications if phosphorus is below the critical level of 12 mg/kg (Colwell P).

In situations where there is a strong stand of clover in conjunction with puccinellia, the nutritive value of both the green and dry feed is significantly boosted to the extent that the dry feed can support liveweight gain. However, there are currently no legumes that can withstand both high salinity and waterlogging so there is little opportunity for pasture legumes to contribute nitrogen to these systems (see Saltland Solution 10 – Legumes for saltland). If this is the case it may be profitable to apply nitrogen fertiliser.

If a saline site will support legumes or has nitrogen applied, the pasture and livestock benefits are significant, including:

- Increased productivity from the puccinellia through the promotion of tillering and improved growth per tiller.
- Improved long-term survival of puccinellia. The plants are stronger, more vigorous and able to tolerate higher levels of salt, flooding or waterlogging.
- Increased development of dormant tiller buds. These become tillers in the following year and this 'sets' the plant up for higher productivity.
- Increased feed quality. Digestibility is often increased but there is little effect on protein unless nitrogen has been applied above the growth demand of the plant.
- Increased seed production. This is a major consideration if the pasture it to be harvested for seed, or if thickening of the sward is needed.

Nitrogen should be used strategically to fill feed gaps (e.g. early winter), rather than routinely as this is rarely economic. From previous work in the Upper South East of SA, application of nitrogen fertiliser in the late autumn – early winter period appears to give the best response economically, particularly for early winter feed. In a trial at Clover Ridge in the upper south east, 25 kg N/ha (50 kg urea/ha) applied after the break of season (while conditions were still relatively warm) gave an additional 150 kg DM/ha in two weeks and 300 kg DM/ha in four weeks. This was a 50% increase in pasture production over the period.

Mid-winter applications may be an appropriate strategy for drier areas (<400 mm) that are unlikely to become excessively waterlogged over winter and therefore risk heavy losses of nitrogen. In colder/wetter areas, this late application is rarely effective because soil temperatures are too low.

RATES OF NITROGEN APPLICATION

Optimal rates are related to rainfall and intended use of the pasture (Table SS6.1). Higher rates are economical if the pasture is used for seed production.

This table should be used as a guide only, as site and seasonal conditions influence fertiliser responses and make it difficult to provide generalised advice.

The form of nitrogen applied (urea, ammonium nitrate, sulphate of ammonia, etc) appears to have little effect on overall response. Therefore the cheapest form, urea, is recommended. To avoid losses by volatilisation, urea should be applied to damp soil or just prior to rain. If this is not practical, apply urea late in the afternoon.

Rising fertiliser costs should also be factored in when making assessments of cost-effective application rates.

Table SS6.1: Suggested rates of nitrogen fertiliser for puccinellia pastures.

Rainfall (mm)	350	400	450	500
Nitrogen (kg/ha)	15-25	20-30	25-40	30-50
Urea (kg/ha)	30-50	40-60	50-80	60-100

GRAZING

Do not set stock until the end of the second growing season after establishment (about 18 months) to allow plants to properly establish, particularly if a lower seeding rate has been used. While it is preferable not to graze during this establishment phase, careful strategic grazing may be possible. Established puccinellia will tolerate hard grazing, but to maintain a vigorous stand, plants should be allowed to set seed at least once every two to three years.

Puccinellia can be grazed in a number of ways depending on the characteristics of each site and pasture system, seasonal conditions and other feed available on the farm.

The greatest economic benefit is usually gained if puccinellia is used to fill the late summer-autumn feed gap reducing the reliance on expensive supplementary feeding. There is an additional benefit from carrying over the standing dry feed to be grazed dry in late summer-early autumn as it shades the soil, preventing the further build up of salinity through evaporation.

While feed quality declines as the plant goes to seed and hays off over the summer period, it still compares favourably with other dry pasture feeds through the summer-autumn period when feed is scarce. This standing dry feed is much more palatable than annual grasses or saltland alternatives such as tall wheatgrass.

Where winter inundation or flooding is likely, it might seem prudent to graze heavily before that time to maximise pasture utilisation while grazing is possible. However, puccinellia is able to survive inundation much better and for longer if the plant shoots are tall enough to remain above water.

Puccinellia stands commonly support 5 DSE/ha when averaged over the year. With appropriate management and fertiliser application, dry matter yields can be nearly doubled and stocking rates of 6-8 DSE/ha supported. At these stocking rates liveweight gains of more than 120 kg/ha and clean fleece weights of more than 20 kg/ha can be produced.

Unlike some saltland grasses (e.g. sea barleygrass), puccinellia seed is not damaging to animals and does not embed itself in wool, so puccinellia paddocks can be used as a weed-seed free zone during the 'grass seed season' for sheep meat and wool production. This strategy relies on the puccinellia pasture being well maintained and therefore sufficiently vigorous to prevent weed (especially sea barleygrass) invasion.

ANIMAL NUTRITION ISSUES

The grazing value of puccinellia depends on its stage of growth. Green leaves in winter and spring have high protein content (15-25%) and high digestibility (60-75%), however this declines as the plant flowers and matures. It remains palatable in late summer and early autumn despite relatively low nutritive value (crude protein less than 5%, digestibility less than 50%). However, anecdotal evidence indicates that protein content in autumn is improved by longer durations of winter-spring flooding. This is conditional on plants not being fully submerged and water not stagnating during the extended flooding. Mineral analysis has shown that several important nutrients (particularly phosphorus) and trace elements (particularly copper) also decline sharply over the summer-autumn period. Hence feed supplementation with hay, lupins or grain, or grazing nearby lucerne, is often recommended to meet this seasonal shortfall in feed quality. Direct mineral supplementation can also be considered.

The best form of supplementation will depend on the particular feed value at the time of grazing and the type of stock. Lactating or growing animals require higher levels of metabolisable energy than other stock. During summer-autumn when puccinellia is low in protein and low in energy, lupins may be used to provide high protein and high energy. Extra hay may be sufficient for normal stock but usually won't provide enough energy for growing or lactating stock. Supplementary feed options and particular stock requirements need to be assessed on a case-by-case basis.

WEED CONTROL

Weeds, particularly sea barleygrass and curly ryegrass, may become an issue in established stands of puccinellia. A farmer-initiated SGSL trial in the Coorong districts achieved some success in controlling sea barleygrass and curly ryegrass through spray-topping.

From the products tested, the best performing spray-top herbicides were found to be:

- Paraquat (135 g/L) and Diquat (115 g/L) [Spray Seed®] at 600 mL/ha; and
- Paraquat (250 g/L) [Gramoxone® /Nuquat®] at 400* mL/ha, and 600* mL/ha.

** Results indicated a trade-off between the rate (which in turn relates to cost) and the duration of effective weed control, for these top performing herbicides.*

In this trial, herbicides were applied from the early tillering to head formation and at the median soft dough stage for sea barleygrass.

While spray-topping of these weeds has proven successful, there is also a risk of curly ryegrass taking over the spaces left if the puccinellia pasture is not sufficiently robust to fill in the gaps. Curly ryegrass is a highly salt-tolerant plant that is very competitive on saline sites but it is even less productive than sea barleygrass. Ensuring adequate phosphorus levels and periodic applications of nitrogen are useful tools to promote the competitive ability of the puccinellia against these weeds, particularly when used in conjunction with chemical control.

RENOVATION

Established pastures that have large bare areas can be roughly cultivated using an implement such as a cultivator with every second tine removed. This will provide suitable areas to trap seed and allow germination, without killing the existing stand. Cultivate only where significant bare areas are present.

A single-tyned ripper can also be used, especially along the edge of existing stands. Early autumn or late spring is the best time to undertake this operation.

Letting the puccinellia seed and mature, so that the seed drops, is another way to let the stand thicken up.

SUPPORTING RESOURCES

Barrett-Lennard, Ed. *Saltland Pastures in Australia – a practical guide*. Available from http://www.landwaterwool.gov.au/products/pr030563.

Edwards, N.J., Hocking Edwards, J.E., Sanders, D. and Revell, D.K. (2002) Sheep production on puccinellia-based pastures in South Australia. *Animal Production in Australia* 24: 293.

Fenton, M.L., Edwards, N.J., McFarlane, J.D., Craig, A.D., Abraham, E.A. and Hocking Edwards, J.E. (2004) Urea applied to puccinellia pastures increases sheep production. *Animal Production in Australia* 25: 241.

Because of the importance of puccinellia for saltland pastures in South Australia, the SGSL publication *Saltland Pastures for South Australia* (Liddicoat, C. and McFarlane, J. 2007) Department of Water, Land and Biodiversity Conservation Report No 2007/08 has a strong focus on puccinellia-based pastures.[52]

Saltland Solution 7

Vegetatively established grasses

IN A NUTSHELL

Plants are established vegetatively for two possible reasons: (a) the plants show poor germination from seed, or (b) the desired genotype is a clone and can only be established from other vegetative material. The planting of material from vegetative sources is quite expensive per hectare, making this method most suited to small areas of saltland, or where time is not critical so sparsely spaced plants can be established and allowed to spread gradually, filling in the gaps over time.

All the vegetatively established grasses in this saltland solution have tolerance to high salt concentrations and high levels of waterlogging. The important saltland species for which this occurs are: *Sporobolus virginicus* (marine couch), *Paspalum vaginatum* (saltwater couch) and *Distichlis spicata* (Distichlis).

SPECIES IDENTIFICATION

The vegetatively established saltland species are all quite similar in that they are creeping, relatively fine-leafed grasses that spread via rhizomes (stems creeping along below the soil surface) or stolons (stems creeping along the soil surface) and often have both. This similarity is highlighted by the fact that while marine couch and saltwater couch are from different genera, they are both called 'couch' and have the typical couch or turf-grass habit. The flower heads are more distinctive, making identification during summer and autumn easier.

Marine couch is a halophytic perennial grass with a world-wide distribution ranging from tropical to temperate latitudes. Saltwater couch was introduced into SA from South Africa in 1935 as a forage for salt affected areas. By 1945, it was being used in WA for similar purposes.

In an investigation of plant adaptation to saline soils near Laidley in the Lockyer Valley, Queensland, marine couch and saltwater couch (established vegetatively) were among the best adapted plants and saltwater couch is widely used on saltland in Queensland.

Distichlis is the genus name of three cloned plants that were introduced into Australia by the American Company NyPa International in the 1990s. NyPa coined the terms 'NyPa Forage', 'NyPa Reclamation' and 'NyPa Turf' to describe these plants. Of these plants, 'NyPa Forage' has been best studied under Australian conditions and is now available through Elders.

There is also a native species *Distichlis distichophylla* or Australian saltgrass which is listed as endangered in NSW. Australian saltgrass is a spreading perennial grass, in the form of a loose, prickly clump of spreading underground stems (rhizomes). The foliage is distinctive, with a row of thin stiff leaves to 50 mm on each side of the stem. It often grows with a similar-looking grass *Sporobolus virginicus*, and is best-distinguished in summer when in flower or fruit.

See SALTdeck to assist with the identification of the 50 most common saltland species.[53]

Figure SS7.1: SALTdeck Identification card for marine couch.

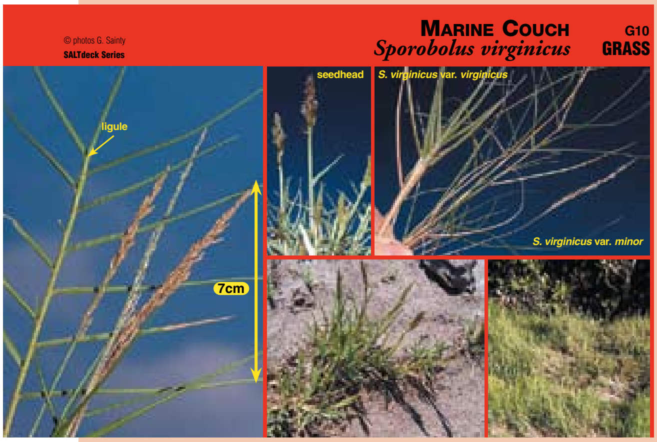


Figure SS7.3: SALTdeck Identification card for Distichlis.

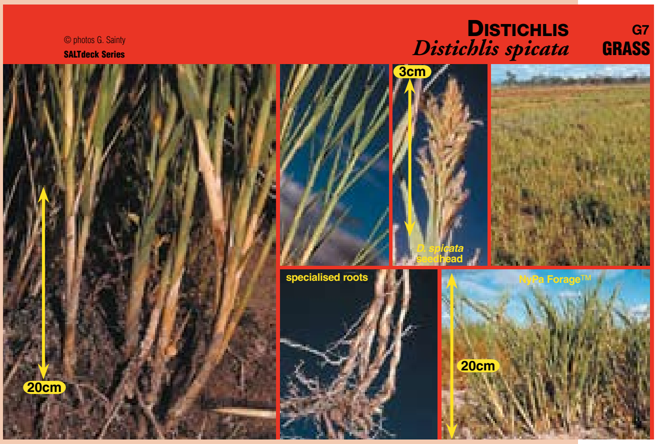
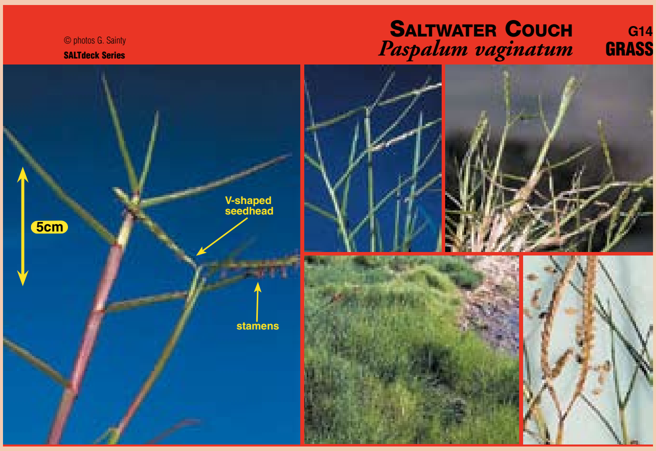


Figure SS7.2: SALTdeck Identification card for saltwater couch.



MOST LIKELY SITUATIONS

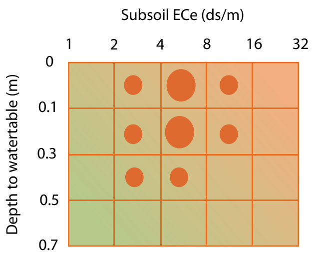
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions, and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and where they are likely to thrive. For vegetatively established grasses, these factors are summarised below.

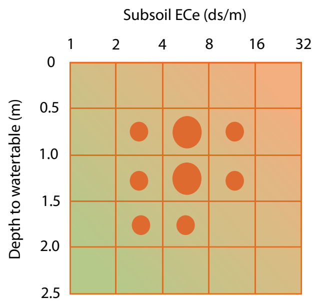
7 – MOST LIKELY SITUATIONS FOR VEGETATIVELY ESTABLISHED GRASSES

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER



SUMMER



DRIVERS OF PLANT ZONATION

- Halophytes and so does best with some salinity;
- Spread vegetatively to fill gaps
- Can tolerate high levels of waterlogging
- Medium tolerance to salinity
- Warm season growers
- Rainfall >450 mm

Key to symbols

● (large) *This is the zone most preferred by vegetatively established grasses and where they are highly recommended;*

● (small) *Vegetatively established grasses are one of the possible options for this zone, but it is outside its preferred conditions.*

COMMON INDICATOR SPECIES

The most suitable areas to establish these vegetative grasses will be very wet (boggy) in winter and may be relatively bare (but still wet or at least moist) in summer. The most common indicator species would be sea barleygrass, cotula, curly ryegrass and perhaps puccinellia in the most waterlogged and saline situations.

SALINITY AND WATERLOGGING REQUIREMENTS

Salt tolerance. These grasses are highly salt-tolerant, but assessing the differences in salt tolerance between the species is not easy. Results vary between trials, between species and between accessions within species. Research in Queensland has shown that marine couch, saltwater couch and Distichlis have relatively similar ranges of salt tolerance, but are highly variable within each species. For example, for marine couch, saltwater couch and Distichlis irrigated with saline water and cut every two weeks for 12-16 weeks, the following ranges of salinity in the irrigation water reduced shoot dry weight by 50%:

- Marine couch: 12 to 37 dS/m (in other words, the most salt-tolerant accession had its yield reduced by 50% when the irrigation water had 37 dS/m, while the least salt-tolerant accession required only 12 dS/m in the irrigation water to reduce growth by 50%).
- Saltwater couch: 13–40 dS/m (depends on accession).
- Distichlis (NyPa Forage): 27 dS/m.

To indicate how salt tolerant these species are, kikuyu had a 50% decrease in shoot dry weight when irrigated with water of EC 4–5 dS/m.

Field observations in NSW have shown that both marine couch and saltwater couch can survive with exceptionally high surface (0-10 cm) soil salinities (EC_e values of 40-100 dS/m).

Waterlogging tolerance. All plants in this category are highly waterlogging tolerant so it is unlikely that any expense associated with improving surface water management would be worthwhile.

If improved surface water management is desired for other reasons (such as preventing surface scalding or making grazing possible) and that management reduces the waterlogging at the site, this may in fact reduce the competitive ability of these vegetatively established grasses. Potentially, improved surface water management (reduced waterlogging) may render a site more suited to a less waterlogging tolerant (but potentially more productive and easier to establish from seed) alternative such as tall wheatgrass.

SOIL AND CLIMATIC REQUIREMENTS

Land capability. While these grass species all tolerate high salinity and high waterlogging, there is little information about the field conditions (soil type, salinity down the profile, depth to watertable etc) to which they are best suited. Anecdotal information relating to Distichlis indicates that the plants grow well over a range of soil types but seem to establish better and spread faster in sandy soils.

Climatic requirements. These vegetative grasses are all C4 species (i.e. subtropical grasses that have little ability to grow at temperatures below about 15°C). This temperature requirement also applies to germination (not relevant in most cases for saltland) and to vegetative establishment.

The widespread use of marine couch on saltland in Queensland is in line with the warm season growth pattern of these vegetative grasses. These species will not be as productive in cold, frosty locations; notwithstanding this, both marine couch and saltwater couch have been shown to perform well on saline sites in inland NSW, and Distichlis has been used commercially in the south-west of WA.

Because these plants are most suited to moist/waterlogged conditions, high levels of plant cover require climatic conditions that can provide significant periods of wetness – so, all else being equal, we would expect much better growth at 700 mm rainfall, than at 400 mm. However, actual rainfall is not always a good indicator as saltland sites usually have a shallow watertable and are low in the landscape, so the moisture requirements of the plants can be provided by a combination of rainfall, water run-on to the site, and contributions from the shallow groundwater.

In other words, these vegetative grasses are likely to be suited to a range of soil types, but rely on there being a combination of salinity and waterlogging during the year to keep them competitive with other species. Once established, they will tend to grow in niches where there is little competition from more vigorous species such as tall wheatgrass.

THE BENEFITS

PRODUCTION

Few scientific data are available about the production potential of these vegetatively established grass species and almost no information is available about animal performance.

Farmers report that both sheep and cattle will effectively graze the vegetatively established grasses but there is little documented information on the levels of animal production that can be expected. Often saline sites remain wet and therefore actively growing when the rest of the farm contains only dry, carry over feed – this greatly increases the 'value' that any saltland pastures can contribute in a whole farm system.

Between 2002 and 2007, some limited research was undertaken on marine and saltwater couch in NSW and Victoria.

Two scalded saline sites on the inland slopes of NSW (Wagga Wagga and Manildra) were selected for an evaluation of 10 accessions of warm-season stoloniferous/rhizomatous grass species, including marine couch and saltwater couch. Most species performed well at Wagga Wagga but only common couch, marine couch and saltwater couch performed at Manildra, where they consistently outperformed the other native species in terms of survival, groundcover and vigour. Saltwater couch had the highest mean vegetative cover at both sites. Overall production was not high – of the order of 1 t/ha over the growing season – though this research was carried out during dry years and probably considerably under-estimates the potential of these species in wetter conditions.

In Victoria, the Sustainable Grazing on Saline Lands (SGSL) research site was located near Hamilton. While the vegetative grasses were not specifically included in the project, the control plots (or volunteer pasture) included a significant proportion of marine couch. Figures SS7.4 and SS7.5 show the pasture and animal performance from the sown and the volunteer pastures. In summary, the volunteer pasture with a significant marine couch component produced from 2 to 4 t/ha of dry matter depending on the salinity of the plots, and this was able to support about half as much grazing as the sown pasture.

WATER USE

There is no information available regarding the water use by the vegetatively established grasses. However, these are grasses that grow actively on saline and waterlogged sites, and they are active during the warmer seasons when water use can be expected to be high – this will be especially true if there is good groundcover and a high leaf area index (ratio of leaf area to soil surface area).

AMENITY AND ENVIRONMENTAL

As with the other potential benefits that may be associated with vegetatively established grasses on saltland, there is little or no scientific information available so we have to draw the likely inferences from other saltland pasture species and situations.

The key to most of the amenity and environmental benefits from revegetating saltland lies in increasing groundcover. This has the benefit of reducing surface soil evaporation and salt build-up, protecting the soil from erosion, and re-establishing some floral and faunal biodiversity. For improved amenity it involves establishing green and growing plants on previously bare saline scalds.

Marine couch, saltwater couch and Distichlis are all used as turf (or amenity) grasses because of their ability to colonise saline sites, and to establish a full mat of groundcover so their amenity value is presumably high.

Marine couch (Sporobolus virginicus) volunteered at the Hamilton SGSL research site in the control plots.

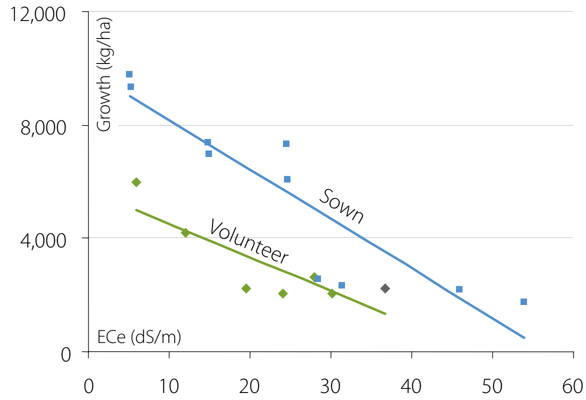


Figure SS7.4: Pasture growth at the Hamilton sites between April and December 2003 and in relation to topsoil salinity measured in December 2003.

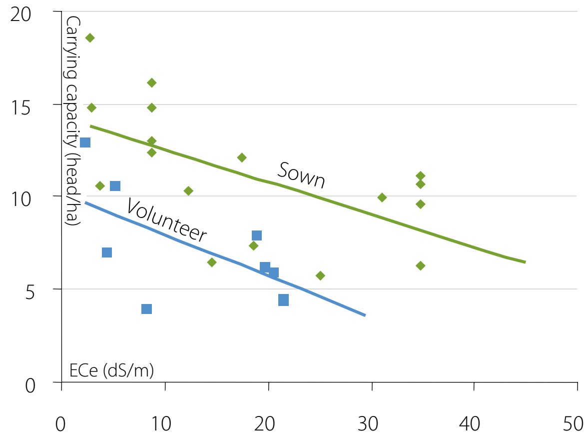


Figure SS7.5: Mean stocking rate for the sown and volunteer pastures in relation to topsoil salinity.

The differences between vegetated and unvegetated areas within a single saltland area can be extreme. Data from the SGSL sites has shown that when soil salinity increases and/or in the absence of vegetation, soil microbial activity and biomass are reduced, being almost zero in soil from bare saline sites. However, in the presence of vegetation, even if the measured salinity is the same, microbial activity is about an order of magnitude higher, but still substantially below the levels found in non-salt-affected pastures. Other research has shown that where Distichlis had been growing for eight years, there were significant improvements in the chemical and physical health of the soil. In other words, the link between improved groundcover and better soil health on saline sites is clear.

From this information, it is easy to conclude that the vegetatively established grasses when allowed to colonise a saline site and grazed conservatively to ensure good groundcover is maintained, can provide a significant boost to both the environmental health of the site and to the visual amenity.

There is increasing institutional support for saltland pastures, including the vegetatively established grasses because of the environmental benefits and amenity they provide. Many organisations that support both agriculture and natural resource management are providing financial support and technical assistance to help farmers assess their saltland, and revegetate it for productive or conservation purposes. Such assistance is on a catchment by catchment basis, so local enquiry is essential.

HOW THE $$$s STACK UP

While the actual costs associated with establishing these grasses have not been documented, establishment is time consuming and expensive because the plants have to be propagated vegetatively and planted individually. In addition, because of their suitability to highly saline and waterlogged areas, production levels will usually be modest. This effectively makes broadacre establishment unlikely. In reality, intensive plantings of these grasses in southern Australia have been (and will likely continue to be) limited to amenity plantings (such as golf courses) and to small saltland areas on farm where costs and returns are not the primary considerations. In strictly commercial grazing situations, Saltland Solutions 1 and 2 may be more suitable options.

Case studies of farmer experience with vegetatively established grasses can be found on the Saltland Genie Website.[54]

ESTABLISHMENT AND MANAGEMENT

PICKING THE RIGHT SPECIES AND VARIETIES

There is extensive diversity within these vegetatively established species – for example marine couch has from 10 to 30 chromosome pairs and its morphology ranges from short (<5 cm) mat-forming ecotypes to tall (~40 cm), erect ecotypes, with fine-textured to coarser leaves. Flowers vary from short compact ovoid panicles to longer narrower ones. This does not apply to the commercial Distichlis cultivar (NyPa Forage), which is a clone.

Given this level of genetic and morphological variation, similar variations in salt tolerance within species is to be expected. Success on the ground is likely to be highly dependent on genotype and therefore (if possible), vegetative material should be collected from sites that are similar to the intended establishment area, and that have the plant characteristics that are required.

In general, there has not been the consistency of demand to develop continuous, or commercial supplies of planting material. Many farmers have collected their own supplies from other saline environments and allowed stands to thicken up over time, though this can be a slow process. Distichlis is commercially available but if marine or saltwater couch are required, then the best place to start is with the turf-grass genotypes as these types will at least be readily accessible and have had some selection applied.

WEED CONTROL

Despite the fact that these vegetatively established grasses are most suited to highly saline and waterlogged sites where few other species will grow well, weed control is still a major issue for establishment. Research with Distichlis showed that survival of planted material was very poor (about 30%) without weed control, but this rose to about 80% if a knockdown spray was used.

There are no specific herbicide recommendations but failure to control weeds greatly increases the risk of either failure or poor initial establishment.

ESTABLISHMENT TECHNIQUES AND TIMING

Studies with Distichlis[55] have used modified vegetable planters to 'sow' the harvested, vegetative material. Trials of different planting systems were undertaken in South Australia and Western Australia and resulted in the adaptation of two broccoli vegetable planters to plant the rhizomes in previously ripped lines. This system was relatively labour intensive and occupied two people to dig and prepare rhizomes and to operate the tractor and planter. A rate of planting of about 2 ha/day was achieved.

There are no reported results from timing of planting trials, but as these grasses do not grow at temperatures below about 15°C, it is not likely that late autumn or winter planting would be appropriate. Spring planting is more suitable, but can be problematic as sites suited to these grasses are likely to be heavily waterlogged (and therefore untrafficable) over winter and early spring. Late spring planting in many situations may not give the planted material sufficient time to establish before the sites dry off in summer.

Therefore, like many of the saltland solutions, the timing of establishment to take account of the site conditions and the plant requirements often means that the planting window can be very narrow and the risk of failure can be higher than for non-saline sites.

These grasses have to be propagated vegetatively and planted individually, making broadacre establishment costly and time consuming. However, as each of these plants spreads laterally by rhizomes and/or stolons, it should be possible to establish relatively continuous stands by planting vegetative material at relatively wide spacings, protecting the material from grazing and allowing the plants to 'fill in' the bare patches. This is especially true where the site is not already supporting other grasses that will compete strongly with the sown species.

Research with Distichlis across southern Australia showed that a rate of spread of approximately one metre per year can be expected under suitable conditions, though this 'rate' tended to slow with time. Rates of spread were also very slow in heavy-textured highly saline soils.

GRAZING OPTIONS AND MANAGEMENT

There is little or no research information regarding the grazing management of vegetatively established grasses. However, there is some anecdotal information and when combined with the general rules for grazing perennial grasses, it can be concluded that:

- Grazing over winter will be minimal due to both the slow growth of these warm season grasses, combined with the fact that most sites suited to these grasses will be heavily waterlogged and therefore highly susceptible to pugging damage.
- Rotational grazing will be better for the persistence of these grasses than continuous stocking. Often, these grasses will be the only green material available over summer, so under continuous stocking, the grazing pressure can be extreme and the grasses will eventually get eaten out.
- The vegetatively established grasses seem to be able to tolerate extremely heavy grazing, provided they are allowed time to recover. Research with Distichlis[56] had one 'plot' that was not fenced off from the rest of the paddock, and so was heavily grazed each year to the point where the plants seemed to have vanished because it was the only green feed available. However, when the livestock were removed, the plants regrew each year without apparent harm and were still spreading slowly after six years of this 'no care' treatment.

ANIMAL NUTRITION ISSUES

Both sheep and cattle will graze these vegetatively established grasses, which are often the only green material available on farms in southern Australia in summer and autumn. This production of out-of-season feed is one of the primary benefits saltland pastures provide to a grazing enterprise.

While there have been very few studies of nutritive value or animal performance associated with these grasses, the following, general conclusions can be drawn:

- There are no known nutritional problems associated with grazing these vegetatively established grasses. They do not accumulate salt, but rather have glands on the leaves that exude salt. Plants that accumulate salt (such as saltbush) can be nutritionally challenging for livestock because of both the high salt content in the diet and the various compounds in the plant material that allow the plant cells to function in the presence of high internal salt concentrations.
- As with all grasses, forage quality (both protein concentration and digestibility) decreases with increasing age of the plant material. A balance is required as long rests between grazings are best for the plants, but produce lower quality feed, while short rests are best for the animals but can reduce the persistence of the plants.
- Forage quality will generally be improved by the use of fertiliser, but on highly saline, waterlogged and poorly productive land, such fertiliser applications may not be economic.
- Summer-growing grasses (whether salt-tolerant or not) are not as nutritious for livestock as cool season grasses. They tend to have higher fibre content (lower digestibility) and lower protein concentrations. There have been some recorded forage quality levels with Distichlis, which varied across a range of sites from 6 to 17% protein and from 45 to 60% digestibility – the higher nutritive values were associated with applications of N and K fertiliser.

Saltland Solution 8

Temperate perennial grasses

IN A NUTSHELL

Limited research reports from as far back as the 1960s have proposed a role for perennial pasture grasses with limited salinity tolerance in the management of saltland. Of the established perennial pasture species, perennial ryegrass (*Lolium perenne*), phalaris (*Phalaris aquatica*) and tall fescue (*Festuca arundinacea*) have been used to some extent on mild saltland. It has also been suggested that the native Australian wallaby grass (*Austrodanthonia richardsonii*) may have some salt tolerance and therefore have a role in the management of mild salinity.

Salt-affected land is often either very patchy or varies from mildly (or non-saline) around the edges to highly saline in the centre of a site. Especially when the saltland areas are of small or moderate size, such variability makes the selection of a single species for sowing quite problematic. These smaller areas of saltland dominate most regions in southern Australia where dryland salinity has become a problem – the exceptions being the Upper South East of South Australia and the wheatbelt of Western Australia, where large areas of reasonably uniform saltland occur.

If sown as part of a shotgun mixture with more salt-tolerant species, these perennial grasses with low salinity tolerance will occupy the least saline and/or waterlogged areas. This can be positive for the saline site as a whole, but can significantly complicate management because the different species can have different management requirements. In particular, the temperate grasses are generally more palatable than more salt-tolerant species and therefore can be eradicated by preferential grazing.

In non-saline situations suited to perennial pastures, phalaris is generally a more productive, stable and reliable species than the other temperate grasses such as cocksfoot, fescue and perennial ryegrass as it has superior long term persistence, deep root development and drought tolerance.

It is likely that these same advantages apply on land with low salinity – as well as seeming to be a little more salt-tolerant than the other temperate grasses mentioned above, when faced with dry conditions over summer, phalaris goes dormant and this may help protect it from the peak salinity levels that often occur at that time.

As far as suitability to mild saltland is concerned, phalaris is followed in order by tall fescue, perennial rye and wallaby grass. Perennial rye is not considered further in this Saltland Solution, though it is sometimes included in shotgun mixtures in high rainfall areas, and nor is wallaby grass which was assessed by the CRC Salinity as having little promise for use on saltland and because seed supply is problematic.

SPECIES IDENTIFICATION

Phalaris (*Phalaris aquatica* L. also known as *P. tuberosa*) is a temperate winter-active perennial grass. It is the most widely-sown, deep-rooted, temperate perennial grass for the high-rainfall zone and adjacent cropping areas in southern Australia. The young plant has no distinctive colouration. The mature plants form dense tussocks of blue-green leaves that have prominent ligules at the collar region.

Tall fescue (*Festuca arundinacea*) is a deep rooted perennial grass, grown principally from southern Queensland through the high rainfall zones of NSW, Victoria and Tasmania and to a lesser extent in SA and WA. The leaves are dark green. The upper surface is dull and has distinct veins along the length of the leaf; the lower surface is smooth and glossy; and the leaf edge is rough to touch. Although a temperate species, tall fescue is more summer-active than phalaris, particularly those varieties from the temperate regions of Europe or from America.

MOST LIKELY SITUATIONS

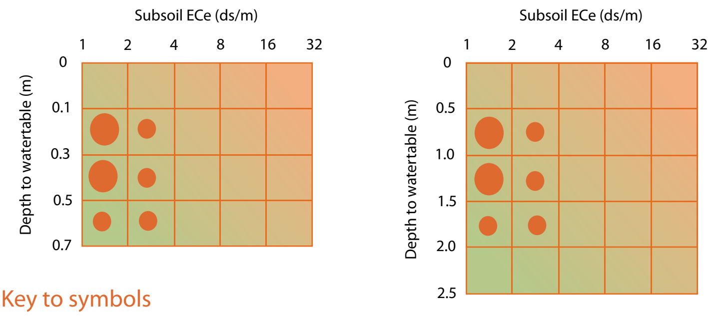
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature, etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and where they are likely to thrive. For the temperate perennial grasses with limited salinity tolerance (i.e. phalaris and tall fescue), these factors are summarised below.

8 – MOST LIKELY SITUATIONS FOR TEMPERATE GRASSES

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER | SUMMER



DRIVERS OF PLANT ZONATION

- Non-halophytes so very limited to salinity tolerance;
- Some tolerance to waterlogging in winter
- Summer growth assisted if access to low salinity groundwater
- >400 mm during the growing season

Key to symbols

● *This is the zone most preferred by the temperate grasses with limited salinity tolerance and where they are highly recommended;*

• *The temperate grasses with limited salinity tolerance are one of the possible options for this zone, but it is outside its preferred conditions.*

COMMON INDICATOR SPECIES

The 'classical' indicator species for saltland (such as sea barleygrass, marine or saltwater couch, water buttons, etc) all tend to indicate levels of salinity and/or waterlogging that will exceed the tolerance of the temperate grasses such as phalaris and tall fescue. The indicator species already mentioned are likely to be towards the centre of a saline site, while the land suitable for phalaris or tall fescue may tend towards the edges of the site.

Around the edges of a saline site, the more likely indicator species for where phalaris and tall fescue might perform well will tend to be those species that are only tolerant of mild salinity and waterlogging – barleygrass, prairie grass, annual ryegrass or Yorkshire fog. These indicator species are quite widespread in mildly saline and non-saline environments and should be considered as weak indicators. See SALTdeck[57] for the identification of the 50 most common saltland species.

SALINITY AND WATERLOGGING REQUIREMENTS

Phalaris seems to be slightly more salt-tolerant than tall fescue but there is not a big difference – neither will be productive if soil salinity (EC_e) exceeds about 6-8 dS/m and are better suited to soils with salinity levels of the order of 4 dS/m. As a general rule, waterlogging and salinity have additive effects on plants, so as the waterlogging at a particular site increases, it is likely that the salinity levels both phalaris and tall fescue can tolerate will decline but there is no specific data for these species.

Tall fescue can tolerate some winter waterlogging and short periods of flooding but it has only moderate drought tolerance compared to phalaris. Therefore, like phalaris, (but even more so), soil water-holding capacity becomes more critical to the overall suitability of tall fescue as average annual rainfall decreases.

For the temperate grasses considered here (phalaris, tall fescue), that are only tolerant of low to moderate salinity, surface water management can be critical. If surface water can be diverted away from the site at low cost, then it is likely that either these grasses will be more productive, or a larger proportion of the saline area will be suitable for them. There are not usually any legal restrictions associated with diverting non-saline surface water away from a saline site in order to reduce inundation and waterlogging.

On the other hand, drainage options that include drawing water from a saline watertable can create disposal problems and are therefore heavily regulated in most jurisdictions – local advice is essential before planning any such drainage.

SOIL AND CLIMATIC REQUIREMENTS

Soils

Phalaris can adapt to a wide range of soils from shallow, sedimentary soils to deep, self-mulching clays. However, it grows best on deep, heavy textured soils with good water-holding capacity and high fertility – or on lighter textured soils if there is a clay subsoil within 30 cm of the surface to retain moisture. Suitable sites may be naturally fertile soils or those having received regular applications of phosphorus or sulphur fertiliser (or both), which promote good clover growth which will meet the high nitrogen requirements of phalaris.

Phalaris can tolerate alkaline and mildly acidic soils but is more sensitive to acidity than cocksfoot, perennial ryegrass or tall fescue and liming will be required if the soil has a pH (in calcium chloride) below 4.5 and high exchangeable aluminium. Most cultivars can withstand waterlogging over winter but not during the warmer months.

Soil type (particularly soil water-holding capacity) becomes more critical to the overall suitability of phalaris as average annual rainfall decreases, because drought tolerance, persistence and plant vigour are all affected.

Tall fescue is suited to a similar range of soils to phalaris and like phalaris, grows best on medium to heavy textured soils that are naturally fertile or well fertilised. Tall fescue will tolerate acid soils and moderate levels of exchangeable aluminium, but is most productive when the pH (in CaCl) is between 5.0 and 6.5.

Climate (rainfall and temperature)

Without taking into account any additional soil moisture that might be available on a saline discharge site, (compared to a non-discharge area), the suitable range for phalaris may be defined as areas receiving more than 300 mm of effective rain between April and October (the main growing season). More southerly areas, with a higher incidence and greater reliability of cool season rainfall, can support phalaris in areas where the total rainfall may be only 450-500 mm/yr while in northern NSW 600-700 mm is needed to ensure adequate rainfall during the growing season from autumn to spring.

Tall fescue is less drought-tolerant than phalaris, so in general, better soil moisture conditions are needed – either from better soils, higher rainfall, or higher altitudes where evaporative demand is lower. While the tall fescue cultivars from Mediterranean-type environments are more winter-active and summer-dormant (like phalaris), those from more temperate areas in Europe and America are less active in winter but grow well over summer when moisture conditions are suitable. This effectively means that the summer-active types are not as suited as the Mediterranean types to the dry summer conditions in southern Australia and vice versa for the summer rainfall conditions in northern NSW.

Both phalaris and tall fescue are highly frost-tolerant (though phalaris generally has better growth rates through winter) and produce a significant proportion of their total annual production in spring.

The comments above about climate are independent of any interaction with salinity – saline sites generally have more water available to support a longer growing season than non-saline sites because of the high watertables. In conditions where the watertable is only mildly saline, both phalaris and tall fescue will be able to utilise some of that extra water and produce more dry matter than from adjacent, non-saline sites. As salinity and/or waterlogging at a site increases, the suitability of phalaris and tall fescue quickly diminishes and tall wheatgrass (see Saltland Solution 5) becomes a more productive and persistent option.

THE BENEFITS

PASTURE PRODUCTION

In the absence of salinity, dryland phalaris or tall fescue-based pastures can produce >8 t/ha in the higher rainfall, higher altitude areas, and 4-6 t/ha in the medium rainfall, lower altitude zones. About 50% of this growth is produced in spring across most districts – in northern, more summer rainfall environments, these species produce significant summer feed, while in southern, winter dominant rainfall zones, summer dormancy and more active autumn growth are expected.

For both phalaris and tall fescue, production falls substantially as salinity increases. When salinity levels exceed about 8 dS/m, production can be negligible, partly because of the direct effect of the salinity on these grasses, and partly because of strong competition from other, more salt-tolerant species. This competition may come from species such as tall wheatgrass that were sown as part of a shotgun mix, or from 'weed' species such as sea barleygrass.

The overall impact on pasture production is likely to be that at the lowest salinity levels, production can be significantly increased due to the better water supply and therefore growing season length, but as salinity increases further towards more moderate levels, these temperate perennial grasses become uncompetitive and are quickly crowded out by other species. Research results from a saline site at Gumble in NSW showed that on a low to moderate salinity site, pasture production of ~3 t/ha was possible with up to 50% of this coming from phalaris.

WATER USE

The water use of these temperate perennial grass species has been widely studied since the issue of dryland salinity started to become significant in the 1980s. The replacement of annual pastures with perennials (principally the temperate perennial grasses and lucerne) across large areas of the medium and higher rainfall zones of southern Australia was strongly advocated and indeed supported with public funding. These perennial-based pastures use more water than annuals and therefore reduce the potential for dryland salinity to further spread. This was seen as a 'win:win' because these perennial pastures are also more productive than the annuals they replaced.

Despite the fact that there is very little information available as to how the water use of phalaris or tall fescue is affected by dryland salinity, we can draw some inferences. The documented ability of phalaris and tall fescue to use soil water for an extended period of the year in non-saline situation probably applies equally well to those mildly saline sites where these species are suited. This applies even more so to the land surrounding saline sites where increased water use can assist in reducing the rate of salinity build-up on the discharge site. The fact that pasture production and carrying capacity of some mild saltland can exceed that from adjacent, non-saline land clearly indicates that additional water is being accessed and used by these perennial species.[58]

Water use on these saline sites (as on non-saline sites) is a function of the amount of green, transpiring leaf that is present. Therefore, if phalaris and/or tall fescue are actively growing on saltland, they will be actively using water. The tendency for phalaris to go dormant over summer limits its ability to use water and to dry the site out prior to the next wet/winter season, but it does give the plant extreme drought tolerance.

AMENITY AND ENVIRONMENTAL

Groundcover is the key to most of the amenity and environmental benefits from revegetating saltland. For the environment this involves reducing surface soil evaporation and salt build-up, protecting the soil from erosion, and as the basis for re-establishing some plant and animal biodiversity. Amenity value comes from establishing green and growing plants on previously bare or weedy saline scalds.

Saline sites where phalaris or tall fescue are suitable options will not usually be bare unless they have been seriously overgrazed – more likely, the site will have been invaded by waterlogging or salt-tolerant weed species such as rushes or sea barleygrass. Even if the site is bare, groundcover can be quickly re-established on this class of saltland simply by fencing and conservative grazing (see Saltland Solution 2 – Fence and volunteer pasture) without the expense associated with pasture establishment. In other words, if groundcover and amenity are the primary motivations behind rehabilitating saltland that is suited to phalaris or tall fescue, then there are cheaper alternatives. These species should only be sown if establishing a productive pasture on the saltland (as well as amenity/environmental gains) is an important objective.

There is increasing recognition of the role that saltland pastures can play in improving catchment outcomes. This is translating into institutional support for saltland pastures, including the temperate perennial grasses, because of the environmental and amenity values they provide. Many organisations that support both agriculture and natural resource management are providing financial support and technical assistance to farmers to assess their saltland, and to revegetate it for productive or conservation purposes. Such assistance is on a State-by-State or catchment-by-catchment basis, so local enquiry is essential.

HOW THE $$$s STACK UP

There are no research results that specifically examine the profitability of establishing temperate perennial grasses with low salinity tolerance on saltland. However, the SGSL program examined the economics of a wide range of potential saltland pasture systems across all the southern States, and concluded:

"Introducing improved pasture species to salt-affected land to increase the feed value for livestock is profitable across a broad range of environments, production conditions and commodity price assumptions. The extent to which farmers can achieve the increases in profit suggested by this study will depend critically on their ability to manage the livestock enterprise to achieve the production levels assumed. Pasture quality and growth were shown to have a major effect on the profitability of improved pastures. Maintaining pasture quality of perennial species requires good grazing management, as long periods of deferment will lead to substantial reductions in feed value."

Applying this general conclusion to saline sites where phalaris and/or tall fescue are suited suggests that saltland pastures can be very profitable. In some cases, such pastures can be more productive than neighbouring, non-saline pastures.[59] The risk for phalaris and tall fescue is that if the conditions are not right (too saline or waterlogged), then production and profitability will be dramatically reduced.

ESTABLISHMENT AND MANAGEMENT

THE RIGHT SPECIES, VARIETIES AND COMPANION LEGUMES

No varieties of phalaris or tall fescue have been selected for salinity tolerance and the relative salinity and waterlogging tolerances of existing varieties are not known so specific advice for saltland is not possible.

We suggest that farmers use varieties that have been proven locally as well-adapted to non-saline land as the seed will be easily available, and the management requirements will be well known.

Phalaris and tall fescue respond well to high nitrogen conditions – to meet this nitrogen demand requires that the pasture contains a strong legume component. The most appropriate companion legumes will be determined by the climate and the salinity and waterlogging levels at the site. The potential companion legumes are examined in Saltland Solution 10 – Legumes for saltland.

WEED AND PEST CONTROL

Once established, phalaris and tall fescue are strongly competitive against weeds, but both (especially tall fescue) have relatively weak seedlings so effective weed control is critical for good establishment. Similarly emerging pastures can be highly prone to insect attack for the first few weeks, but are relatively resistant once established.

Carolynn Ive stands in a highly productive phalaris pasture established on a previously badly eroded saline and acidic site that supported very poor vegetation. Photo: John Ive

Establishing these grasses on saline sites does not reduce the need for weed control, even if the site appears to be quite bare – the very act of sowing the pasture will usually stimulate a significant weed germination. As with new pastures for non-saline areas, weed control on the site should commence in the year prior to sowing. Most of the problem weed species on saline sites will be annuals and it will be essential to reduce their seed set in the spring of the year prior to pasture establishment. It is particularly critical to control annual grass weeds as there are no selective herbicides that can remove annual grasses from phalaris or tall fescue pastures. Spring weed control can be done with either a knock down or a selective herbicide depending on the weed species. If the site is bare over summer, soil salinity levels will increase, so it is important not to graze the site after herbicide application. This is even more important if the site is erosion prone.

If other weeds common to saline areas (such as Juncus or rush species, or summer-growing grasses such as marine couch that are harder to control than the annual weeds) are present on the site, there may be specific management requirements to control them so seek advice from a local agronomist before implementing a weed control program. Follow up weed control at the time of sowing is also essential. For more details on weed control see the Saltland Genie website.[60]

ESTABLISHMENT TECHNIQUES AND TIMING

The most common sowing time for both phalaris and tall fescue on non-saline sites is autumn/early winter (i.e. April to June) after the opening rains – the later the sowing date, the slower the emergence and early growth and therefore, the greater the need for excellent weed control. In higher rainfall areas, spring sowing can also be successful if there is significant rainfall during spring and summer.

Establishment on saline sites should aim for similar times of sowing as non-saline sites, but this is complicated by the fact that saline sites often become untrafficable soon after the opening rains, greatly reducing the time available for pasture establishment. Similarly, with spring sowing, the site may not dry off sufficiently to sow a pasture until late in spring, giving the grasses insufficient time to establish a substantial root system to allow them to survive the first summer.

Neither species is suited to sowing with a cover crop such as barley (that is suited to similar salinity conditions) because the seedlings are uncompetitive and usually will not develop sufficiently to survive over the first summer.

Depending on the site and available equipment, both phalaris and tall fescue can be direct drilled, or sown into a conventional seedbed, as long as the sowing depth does not exceed about 1.5 cm. Direct drilling is usually preferred as saline sites often have high erosion potential.

Phalaris has a slightly more vigorous seedling and can be successfully established by aerial seeding – for modest-sized saline sites, this means 'hand' spreading is a viable option for phalaris but not for tall fescue.

In summary, the best time to establish these temperate perennial grasses is as soon as possible after the autumn rains have germinated the first flush of weeds. These weeds must be controlled mechanically or chemically at the time of sowing the pasture. Spring sowing becomes more viable in northern, more summer dominant rainfall zones where there is likely to be follow up rainfall to ensure survival over the first summer.

To ensure successful establishment of the pasture, it is best to avoid grazing in the spring following sowing – the pasture can then be grazed down in late summer/ autumn in preparation for the opening rains.[61]

FERTILISER AND SOIL AMELIORATION

Both phalaris and tall fescue have been selected to perform well under relatively high levels of soil fertility. It is likely that if the soil fertility is low, when added to the stress associated with salinity, then these 'improved' species will struggle to persist.

As with pastures for non-saline land, a current soil test of the area is the best approach to sensible fertiliser and ameliorant (lime or gypsum) decisions. Saline soils can have a quite different pH to adjacent, non-saline land – sometimes more acid, sometimes more alkaline. Neither phalaris nor tall fescue can tolerate highly acid soils, so lime application may be needed. However, the need to apply high rates of lime or gypsum to a saline site can dramatically reduce the profitability associated with the pasture establishment and this needs to be carefully considered.

At the time of sowing, a 'starter' fertiliser with added nitrogen will be more effective than superphosphate alone because saline sites usually have a history of very low legume content so there will not be a strong bank of soil nitrogen for the grass seedlings to access.

GRAZING OPTIONS AND GRAZING MANAGEMENT

There is a wealth of information about grazing management for these temperate perennial grasses because of their widespread use in non-saline grazing systems. With a little adjustment to account for the fragile nature of many saline sites, the principles from non-saline perennial pastures can be applied directly to saltland situations. The general rules for grazing perennial grasses, modified for saltland situations include:

- Grazing over winter will be minimal due to both the relatively slow growth of phalaris and tall fescue and to the fact that most saline sites will be waterlogged during winter and therefore highly susceptible to pugging damage.
- Rotational grazing is better for the production and persistence of these temperate grasses than continuous stocking, and should be considered mandatory for saline sites. Often, these saline sites will be providing the only green material available over summer, so under continuous stocking, the grazing pressure can be extreme and the perennial grasses will soon get eaten out.
- Because there are usually environmental and amenity benefits being sought from saltland pastures, the grazing management should be slightly more conservative than for similar pastures on non-saline land. Both phalaris and tall fescue can tolerate hard grazing – but many saline sites are too fragile to stand up to such heavy grazing pressure without pugging damage or erosion risk. In general, the rests between grazing should be longer than for conventional pastures and more 'residual' pasture should be left behind when the stock are removed to ensure rapid regeneration and sufficient groundcover to minimise evaporation from the soil surface.
- To encourage persistence, these perennial grasses should be allowed to flower and set seed at least every second year, slightly more frequently than is recommended on non-saline sites.
- The MLA publication *Towards Sustainable Grazing – the Professional Producers Guide* and the on-line sheep industry package Making More from Sheep contain up-to-date information about grazing management of these perennial grass-based pastures.[62]

ANIMAL NUTRITION ISSUES

Phalaris and tall fescue have been extensively selected to be suitable for animal grazing. They are productive, nutritious and can provide extended grazing for much of the year if the moisture conditions are suitable. There have been many studies of their nutritional value. Key conclusions include:

- There are no special nutritional problems associated with grazing these perennial grasses when they are growing on saltland. They only survive if the salinity levels in the soil are low, and they do not accumulate salt in the leaves.
- As with all grasses, forage quality (both protein content and digestibility) decreases with the age of the plant material. A balance is required as long rests between grazings are best for the persistence of the plants, but give lower feed quality, while short rests between grazings give higher feed quality (good for the animals) but can reduce the persistence of the plants. On saltland, the primary concern is often maintaining groundcover and pasture persistence, so less frequent grazing with slightly lower forage quality is usually the right balance.
- Forage quantity and quality will generally be improved by the use of fertiliser and/or by the inclusion of companion legumes so management and fertiliser strategies should focus on promoting good legume production.
- Under certain conditions, both phalaris and tall fescue can be poisonous to livestock, especially sheep.
- Phalaris poisoning generally occurs in autumn or early winter and can come in two forms; sudden death syndrome and staggers. Sudden death syndrome tends to be associated with hungry animals being put onto short, actively growing phalaris shoots that may have been stressed with lack of water or by frosts – deaths usually occur within 48 hours of introduction to the pasture. There is no cure and the animals should be removed from the pasture. Phalaris staggers are caused by the ingestion of alkaloids found in green phalaris shoots – stock need to be grazing this pasture for at least a couple of weeks before symptoms occur. Stock can appear quite normal, then break down and stagger or throw themselves on the ground and convulse. Signs may persist for several weeks, however due to the damage to the spinal chord that is caused by the condition, animals never fully recover. Phalaris staggers can be prevented with cobalt supplements.
- Tall fescue often has an endophyte fungus living within the plant. This fungus improves the persistence of the plants, but under certain conditions the endophyte can produce alkaloids that are toxic to livestock, causing summer ill thrift and lameness. Modern cultivars have been infused with new strains of the fungus that protect the plants from insect attack but do not produce toxic alkaloids.

These nutritional disorders are unlikely to occur on saltland pastures if there is a wide array of different forage plants, so that animals do not get to ingest a single pasture type.

SUPPORTING RESOURCES

Barrett-Lennard, Ed. *Saltland Pastures in Australia – a practical guide*. Available from http://www.landwaterwool.gov.au/products/pr030563.

Liddicoat, C. and McFarlane, J. (2007) *Saltland Pastures for South Australia*. Department of Water, Land and Biodiversity Conservation Report No 2007/08. This is a product of the SGSL initiative, providing a wealth of information that will be of value beyond SA. It can be ordered from http://www.landwaterwool.gov.au/products/px071257-0.

Masters, David G., Benes, Sharon E., Norman, Hayley C. (2007) Biosaline agriculture for forage and livestock production. *Agriculture, Ecosystems and Environment* **119**, 234–248.

Nichols, P.G.H. et al (2008) Production and persistence of temperate perennial grasses and legumes at five saline sites in southern Australia. *Australian Journal of Experimental Agriculture* **48**, 536–552.

White, R.E. et al (2003) SGS Water theme: influence of soil, pasture type and management on water use in grazing systems across the high rainfall zone of southern Australia. *Australian Journal of Experimental Agriculture* **42**,907-926.

Grasslands Societies of Southern Australia [http://www.grasslands.org.au/] and NSW [http://www.grasslandnsw.com.au/] have lots of information about phalaris and tall fescue in NSW and Victoria, though not usually in a saline environment.

The website http://www.wool.com.au/Pastures/Introduction_to_Australian_Pastures/page__2122.aspx has a good overview of current and recently completed research into the temperate pasture species, including current breeding efforts.

The *National Dryland Salinity Program* (NDSP 1993–2003) was the first national attempt to better understand the causes, impacts, costs and management options for preventing and/or overcoming dryland salinity. The final year of the program was dedicated to harvesting the knowledge and making it available to the diverse range of stakeholders through the Managing Dryland Salinity in Australia resource kit. http://www.ndsp.gov.au/. An update was published by Land & Water Australia in 2006. http://www.lwa.gov.au/.

Subtropical grasses

IN A NUTSHELL

The subtropical grasses included in this Saltland Solution have commercial seed supplies, have some salinity and/or waterlogging tolerance and are widely used in non-saline pastures. Kikuyu can be established from seed or from vegetative plantings, but is included in this Saltland Solution rather than with the vegetatively established pastures because unlike marine couch, saltwater couch and Distichlis, it can be established from seed and because it has only limited tolerance to salinity.

As with the temperate grasses with limited salinity tolerance, these subtropical species can have an important place in saltland management because salt-affected land is often either very patchy, or varies from non-saline land around the edges of a saltland site to highly-, severely- or extremely-saline land in the centre. Small or highly variable sites are particularly suited to shotgun mixtures rather than trying to establish a single species across the site.

There are a number of subtropical grasses available in Australia, but of these, our investigations suggest that only two species have sufficient salinity and waterlogging tolerance to be considered as Saltland Solutions. These are kikuyu (*Pennisetum clandestinum*) and Rhodes grass (*Chloris gayana*) which are the focus of this Saltland Solution even though local shotgun mixtures often include other subtropical species with lower salinity tolerances, for example, bambatis panic seems to be a good bet for the hard-setting clays in northern NSW and is reputed to have some salt tolerance.

There is limited experience (producer or research) with growing these subtropical grasses on saline sites, but they are widely grown on non-saline land in northern NSW and in the south coast and northern agricultural regions of WA and it is in these districts that they are most likely to be useful for saline sites. On the other hand, if they are not successfully grown on non-saline land in your district they are unlikely to grow well on saline sites, where they must deal with the added stresses of salinity and waterlogging.

Kikuyu and Rhodes grass will grow well in soils of low salinity (EC_e 2-4 dS/m) and also into the moderate salinity (EC_e 4-8 dS/m) range. Both are spreading grasses: Rhodes grass has runners (stolons) while kikuyu has both runners and rhizomes (underground runners). This spreading habit means they will spread vegetatively to fill-in gaps which is an advantage on saline sites as soil salinity can inhibit recruitment from seed. However, kikuyu's strongly creeping habit means that over time it can dominate mixed swards and is often sown in non-saline situations without other grasses because of this. Rhodes grass is more suited to mixed swards.

New salt-tolerant varieties of Rhodes grass are available, but these were predominantly developed for the Middle Eastern market and for irrigation with brackish water on well-drained soils, rather than poorly drained saline soils in southern Australia. The performance of these 'salt tolerant' varieties has yet to be evaluated in southern Australia.

Subtropical grasses require warm soils (soil temperature >15°C) to germinate plus total weed control during establishment as the seedlings compete poorly with weeds. Sowing time varies from mid- to late August in the northern agricultural regions in WA to early, or even late summer in northern NSW.

Where these subtropical grasses with limited salinity tolerance can be used on and around saltland, they have the great advantage of producing green feed over summer, a commodity that is often rare on the rest of the farm.

MOST LIKELY SITUATIONS

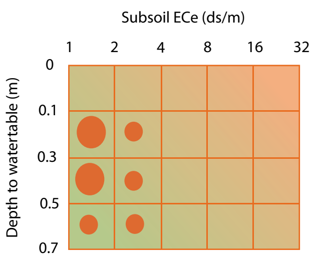
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions, and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature etc) and soil (salinity, texture, waterlogging, etc) factors which determine where they will be able to survive, and where they are likely to thrive. For subtropical grasses with limited salinity tolerance, these factors are summarised below.

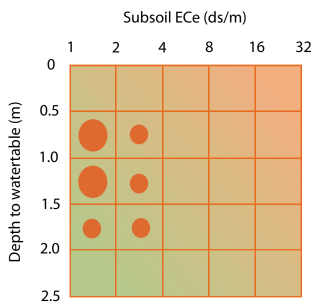
9 – MOST LIKELY SITUATIONS FOR SUBTROPICAL GRASSES

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER



SUMMER



DRIVERS OF PLANT ZONATION

- Non-halophytes so limited to salinity tolerance
- Tolerate some waterlogging in winter – kikuyu more than Rhodes grass
- Growth in summer assisted if low salinity groundwater accessible to roots
- Rainfall 400-600 mm

Key to symbols

- ● (large) *This is the zone most preferred by kikuyu and Rhodes grass where they are highly recommended and/or where they will most likely grow well.*
- ● (small) *Kikuyu and Rhodes grass are options for this zone, they should survive well, but it is outside their preferred conditions.*

SPECIES IDENTIFICATION

Kikuyu and Rhodes grass are relatively easy to identify. Rhodes grass (*Chloris gayana*) is a subtropical/summer active perennial grass. It is a tufted grass that sends out strong, above ground runners (stolons), allowing it to spread rapidly. This can be a great advantage on saltland where soil salinity often inhibits recruitment from seed. It has a very characteristic seed head that looks like the fingers of a hand – see Figure SS9.1.

Kikuyu (*Pennisetum clandestinum*) is a highly stoloniferous (i.e. creeping) subtropical grass, widely used as a domestic lawn species. In agriculture, kikuyu is the base pasture for much of the dairy industry in northern NSW and southern Queensland. If not heavily grazed (or mown), kikuyu can form dense swards to 50 cm in height. The seed heads are hidden (thus the name *clandestinum*) but when in flower, the male stamens are highly visible – see Figure SS9.2. The creeping nature of kikuyu makes it ideally suited to low to moderate salinity land, where it can 'thicken up' if initial establishment from seed is limited.

Figure SS9.1: SALTdeck Identification card for Rhodes grass.

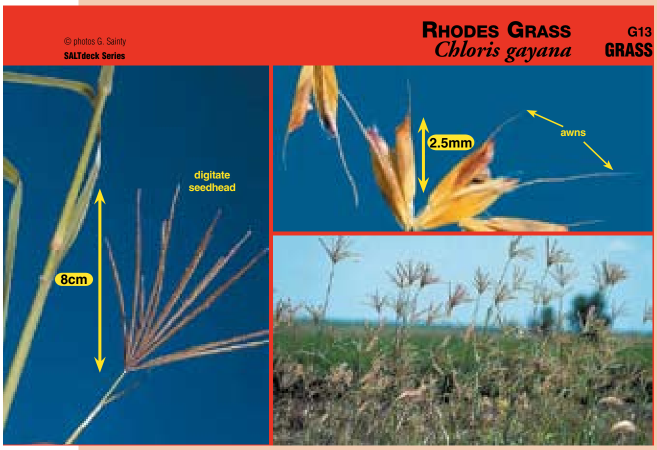


Figure SS9.2: SALTdeck Identification card for kikuyu.

COMMON INDICATOR SPECIES

The 'classic' indicator species for saltland (such as sea barleygrass, marine or saltwater couch, water buttons, etc) all tend to indicate levels of salinity and/or waterlogging that will exceed the tolerance of the subtropical grasses such as Rhodes grass and kikuyu. The classic indicator species mentioned above are likely to be towards the centre of a saline site where the salinity levels are typically highest, while the land suitable for subtropical grasses will tend to be towards the edges of the saline site and in the surrounding non-saline areas.

The more likely indicator species for where the subtropical grasses might perform well will tend to be those species that are similarly tolerant of moderate salinity and waterlogging – barleygrass, annual ryegrass or windmill grass (a native, warm season grass). These 'indicator' species are quite widespread in mildly saline and non-saline environments, and should be considered as 'weak' indicators unless they are specifically located around the margins of more saline land.

SALINITY AND WATERLOGGING REQUIREMENTS

Data on salinity tolerance of these species under production conditions is limited, however comparative research with marine and saltwater couch and Distichlis irrigated with saline water, showed that shoot dry weight by was reduced by 50% for the couch and Distichlis species over the range 15-40 dS/m.

In contrast, kikuyu had a 50% decrease in shoot dry weight at a mere 4–5 dS/m. Rhodes grass and kikuyu are generally considered to have similar salinity tolerances, although NSW information has indicated that 6.6 dS/m in irrigation water was required to reduce Rhodes grass growth by 10%, while only 4.1 dS/m was required to reduce kikuyu growth by 10%. Note: salinity levels measured in the soil are not directly comparable with measuring the salinity of applied irrigation water

In summary, both kikuyu and Rhodes grass will grow well in soils with low salinity (2-4 dS/m) and to a lesser extent in soils with moderate salinity (4-8 dS/m).

Waterlogging is damaging to the growth of subtropical grasses by reducing the oxygen supply to the roots. Plants that are highly tolerant of waterlogging usually have special 'pipes' in their roots to bring air from the soil surface. For the subtropical grasses, and others that are not highly salt-tolerant, any increase in waterlogging reduces the tolerance for salinity.

For the subtropical grasses (i.e. kikuyu and Rhodes grass), that have only limited salinity tolerance, surface water management can be critical. If surface water can be diverted away from the site at low cost, then it is likely that either these grasses will be more productive, or a larger proportion of the saline area will be suitable for them. There are not usually any legal restrictions associated with diverting non-saline surface water away from a saline site in order to reduce inundation and waterlogging.

On the other hand, drainage options that include drawing water from a saline watertable can create disposal problems and are therefore heavily regulated in most jurisdictions – local advice is essential before planning any such drainage.

SOIL REQUIREMENTS

Rhodes grass is widely adapted across many soil types. It performs best on light to medium textured soils as some establishment difficulties have been reported on heavy soils. Soils need to be reasonably well drained as Rhodes grass has poor tolerance of waterlogging. Rhodes grass does not tolerate extreme soil acidity and high exchangeable aluminium levels. High levels of soil fertility are required to support high yielding Rhodes grass pastures.

Kikuyu is widely adapted across many soil types, similar to Rhodes grass, and is naturalised on many of the higher fertility, coastal soils. It is more waterlogging-tolerant than Rhodes grass and performs well on medium and well-drained soils with high fertility. Kikuyu is highly tolerant of acid soils.

CLIMATIC REQUIREMENTS

Kikuyu and Rhodes grass are C4 species that require temperatures in excess of 15°C for their photosynthetic pathway to operate. From a salinity management perspective, this means these species are only suited to coastal regions, to the northern agricultural region in WA and to central and northern NSW.

Both are reasonably hardy and will respond well to summer/autumn rain. For saline sites where salinity levels often build up over summer, this summer rainfall is probably essential for leaching salt out of the topsoil and keeping the salinity levels within the range that can be tolerated by the subtropical grasses. If the saline site has a relatively shallow watertable that is only mildly or moderately saline, these subtropical grasses are deep rooted and will be able to access this groundwater.

Both species prefer frost-free climates, although both will survive in frost-prone areas that have summer rainfall, such as the northern slopes of NSW.

THE BENEFITS

PRODUCTION

Rhodes grass and kikuyu are highly productive subtropical grasses, capable of yields in excess of 20 tDM/ha under high rainfall and high fertility. In practice however, yields will be much lower than this on non-saline land, and lower still if salinity and/or waterlogging are present – though definitive studies have not been carried out.

For both kikuyu and Rhodes grass, production falls substantially as salinity increases because of their limited salinity tolerance. When salinity levels reach the upper level of the moderate salinity range (8 dS/m), production will probably be negligible, partly because of the direct effect of the salinity on these grasses, and partly because of strong competition from other, more salt-tolerant species. This competition may come from species such as tall wheatgrass that were sown as part of a shotgun mix, or from 'weed' species invading the saline area.

Countering this trend is the fact that the growing season on saltland is typically greater than for surrounding soils because of the greater water supply. If Rhodes grass and kikuyu have access to moisture over summer on land with low to moderate salinity, then production can be high. Most likely though, production on saltland will be small due to the effect of salinity and the generally low nitrogen status of saline areas – although even small yields can be valuable if produced 'out of season' when green feed is not available on other parts of the farm.

AMENITY AND ENVIRONMENTAL

Both kikuyu and Rhodes grass are deep-rooted, summer-growing species and therefore able to use much more water over summer than their more-temperate, winter-growing relatives.

Groundcover is the key to most of the amenity and environmental benefits from revegetating saltland, and both Rhodes grass and kikuyu are capable of rapid spread via stolons. For the environment, this involves reducing surface soil evaporation and salt build-up, protecting the soil from erosion, and as the basis for re-establishing some plant and animal biodiversity. Amenity value comes from establishing green and growing plants on previously bare or weedy saline scalds.

However, while that is true in general for saline sites, those sites that will support Rhodes grass and/or kikuyu are only mildly saline and will not usually be bare unless they have been seriously overgrazed. It is more likely that such sites will have been invaded by waterlogging- or salinity-tolerant weed species so the amenity and environmental gains may be relatively minor.

Even if such a site is bare, groundcover can be quickly re-established on this class of saltland simply by fencing and conservative grazing (see Saltland Solution 2 – Fence and volunteer pasture) without the expense associated with pasture establishment. In other words, if groundcover and amenity are the primary motivations behind rehabilitating saltland that is suited to subtropical grasses, then there are cheaper alternatives. These species should only be considered if establishing a productive pasture on the saltland (as well as amenity or environmental gains) is one of the objectives.

There is increasing recognition of the role that saltland pastures can play in improving catchment outcomes and this is translating into institutional support for saltland pastures, including the subtropical grasses because of the environmental and amenity values they provide. Many organisations that support both agriculture and natural resource management are providing financial support and technical assistance to assist farmers to assess their saltland, and to revegetate it for productive or conservation purposes. Such assistance is on a State-by-State or catchment-by-catchment basis, so local enquiry is essential.

HOW THE $$$s STACK UP

The Sustainable Grazing on Saline Land (SGSL) program showed that across southern Australia, saltland pastures could provide a profitable investment. The final report from the SGSL Economics Theme stated: "*Introducing improved pasture species to salt-affected land to increase the feed value for livestock is profitable across a broad range of environments, production conditions and commodity price assumptions, according to the results of this study.*"

There are several factors that can undermine the profitability from saltland pastures, and we can apply these general conclusions to the subtropical grasses:

- **Infrastructure** costs can be a relatively significant factor for any saltland pasture if fencing and water are required for a small site.
- **Establishment** costs are a primary determinant of profitability and can vary greatly for different saltland systems (in the SGSL program, the variation across 20 farm sites in WA was from $77 to $324/ha).
  In general, the costs of establishing a pasture based on subtropical grasses will be similar on saline or non-saline sites.
- Risk of **failure** is significantly higher than for non-saline pastures, particularly if the site is waterlogged or sodic (as is often the case), as well as being saline. Sowing subtropical grasses is inherently more risky because they have to be sown in spring when soil temperatures are rising and soils are often drying out, and this risk may be increased on saline sites.
- Pasture **productivity** – for most plants, including the subtropical grasses, the saltier the site, the lower the pasture and animal production that can be expected.
- **Nutritive value** of the pasture – many saltland species contain either salt or other compounds in the leaves that help them survive the inhospitable saline environment, but that can be detrimental to grazing animals. The subtropical grasses do not have any of these limitations so nutritionally, we can expect them to be similar to their non-salt-tolerant relatives.
- **Product prices** – the cost of ongoing inputs such as fertiliser or supplements and the prices paid for meat and wool products will always impact on the 'bottom line' of any pasture system and the subtropical grasses are no exception.

In conclusion, the subtropical grasses are likely to be profitable if used in the appropriate, mildly saline circumstances. However, these circumstances (i.e. warm temperatures, summer rainfall, mild salinity, limited waterlogging and reasonable soil fertility) are not widespread. Farmer case studies on the use of subtropical grasses on saline land can be found on the Saltland Genie website.[64]

ESTABLISHMENT AND MANAGEMENT

CHOOSING THE RIGHT VARIETIES

None of the varieties of kikuyu or Rhodes grass reported here have been selected for salinity tolerance and the relative salinity and waterlogging tolerances of existing varieties have not been documented so specific advice for saline sites is not possible. [Note – there are some Rhodes grass varieties that have been selected for use on sandy soils with saline irrigation water in the Middle East, but they have not been tested on saline sites in Australia]. We suggest that farmers use varieties that have been proven locally as well-adapted to non-saline land as the seed will be easily available and there will be local experience to draw on.

Rhodes grass varieties

Pioneer (also known as commercial Rhodes grass) was introduced from South Africa in 1903. It is an early-flowering, erect plant with moderate leafiness and is probably the most drought-resistant variety. It runs to head quickly throughout the growing season, so its feed quality drops quickly. It has been superseded by Katambora.

Katambora is later flowering than Pioneer, so remains more leafy and productive into autumn. It is also finer leaved, more stoloniferous and perhaps more drought resistant.

Callide, released in 1963, is later flowering than Katambora, is less cold-tolerant and needs a higher rainfall than Pioneer or Katambora, but is more palatable and can be more productive than Pioneer or Katambora under conditions of higher fertility.

Finecut is a recently released variety that has been selected for its improved grazing qualities. It has fine leaves and stems, is early flowering, of uniform maturity and high yielding. Finecut was derived from Katambora.

Topcut is a recently released variety developed from Pioneer that has been selected for improved haymaking qualities. It has fine leaves and stems, is early flowering, of uniform maturity and is high yielding.

Nemkat is a recently released variety bred from Katambora types.

Kikuyu varieties

Whittet, the only commercially available variety, is a proven soil stabiliser with good quality summer feed when well fertilised and heavily grazed.

Rhodes grass and kikuyu respond well to high nitrogen conditions – to meet this nitrogen demand requires that the pasture contains a strong legume component. The most appropriate companion legumes will be determined by the climate and the salinity and waterlogging levels at the site (see also Saltland Solution 10 – Legumes for saltland).

Lester McCormick (left), Technical Specialist (Pastures), NSW DPI, and Devevan Ellis identifying the grasses for the field day participants.
Photo: S. Murphy

WEED AND PEST CONTROL

Established stands of kikuyu and Rhodes grass are strongly competitive against weeds. In the right conditions both, but especially kikuyu, can choke out all other competition, including desirable companion species. However, both kikuyu and Rhodes grass are much less competitive as seedlings, and this is likely to be especially the case if sown into saline sites. In such a location, it is likely that other species which would normally be easily out-competed by the subtropical grasses will be advantaged by the saline conditions and compete much more vigorously.

Weed control during the establishment phase is critical for all subtropical grass-based pastures, and even more so in saline situations. The likely weeds will differ from region to region and depend on the sowing time, but as with new pastures for non-saline areas, weed control on the site should commence in the year prior to sowing.

Most of the problem weed species on saline sites will be annuals and it will be essential to reduce their seed set in the spring of the year prior to pasture establishment if autumn sowing is planned. Autumn sowing may not be ideal for the subtropical grasses in southern Australia, but if they are sown as part of a shotgun mix on saline sites, there will be many compromises to account for the range of species in the mix, and autumn sowing is often selected. There are no selective herbicides that can remove annual grasses from these subtropical based pastures so site clean-up in the previous spring is critical.

For spring sowing (probably the best option for these frost-sensitive species), there is more latitude with weed control because a knockdown herbicide followed by direct drilling will give the subtropicals a full growth season before annual weeds reappear. However, as discussed above, when shotgun mixes are sown on saline sites the selection of weed control and sowing times will affect which species get the best chance to establish.

Ensure that pre-planting weed control does not produce a bare site over summer, as salinity levels will increase in the surface soil, making subsequent establishment of sown pastures more difficult. This is doubly the case if the site is erosion prone.

If other weeds common to saline areas (such as Juncus or rush species, or summer growing grasses such as marine couch that are harder to control than the annual weeds) are present on the site, there may be specific management requirements to control them so seek advice from a local agronomist before implementing a weed control program.

Neither Rhodes grass nor kikuyu are particularly susceptible to attack by insect pests or diseases and usually no specific control measures are required. On the other hand, if legumes are included in the pasture mix, insect attack, especially from red legged earth mite and lucerne flea are highly likely and control measures will be needed – see Saltland Solution 10 – Legumes for saltland.

ESTABLISHMENT TECHNIQUES AND TIMING

Depending on the site and available equipment, both kikuyu and Rhodes grass can be direct drilled, or sown into a conventional seedbed, as long as the sowing depth does not exceed about 5-10 mm for Rhodes grass or 20 mm for kikuyu. Direct drilling is usually preferred as saline sites often have high erosion potential. Rhodes grass seed is extremely 'fluffy' and difficult to sow through conventional machinery as the seeds 'bridge' in the seedbox. Pelleting the seed overcomes this problem, but it is expensive. One common solution is to mix the seed with fertiliser and then broadcast it, followed by harrowing and/or rolling to ensure seed/soil contact – another is to sow the Rhodes grass through the grain box of a combine, with the seed mixed with a 'carrier' such as sawdust, sand or killed grain.

The best time to establish these subtropical grasses is after a knockdown spray in spring to kill the existing weeds. Other considerations for seeding include:

- Seeding depth – Rhodes grass requires precise, shallow seeding at 5-10 mm, while kikuyu has a comparatively larger seed and can be sown at from 10 to 25 mm.
- Seed quality of Rhodes grass varies widely and needs to be checked at the time of purchase, while kikuyu seed normally has excellent germination.
- Rhodes grass seed is light and fluffy and difficult to handle using conventional seeding machinery, either use a 'carrier' like sand or fertiliser or use coated seed.

There are significant management issues associated with the incorporation of subtropical grasses into shotgun mixes. If sown with more salt-tolerant species such as tall wheatgrass or puccinellia, these subtropical grasses with limited salinity tolerance will occupy the least-saline and/or waterlogged areas. To begin with, the temperate species are best sown in autumn, while the subtropicals are best sown in spring, or even summer in northern NSW.

FERTILISERS

Like the temperate perennial grasses, the subtropicals perform best if well supplied with nitrogen, and so the inclusion of legumes with some salt- and waterlogging-tolerance in the seed mix is usual. Winter annual legumes are generally most likely to be compatible with the subtropical grasses because they do not have to compete with the aggressively growing summer-actives. The range of suitable legumes is covered in Saltland Solution 10 – Legumes for saltland, but there are no outstanding candidates for inclusion with subtropical grasses.

There are standard recommendations for fertiliser use on subtropical grasses in those districts where they are commonly used as pasture species. As there is no specific information about the fertiliser needs of these species on saltland, the only solution is to assume that the recommendations for non-saline land are applicable. As with pastures on non-saline land, a current soil test of the area is the best approach to sorting out a sensible fertiliser and soil ameliorant (lime or gypsum) requirements.

At the time of sowing, a 'starter' fertiliser with added nitrogen will be more effective than superphosphate alone because saline sites usually have a history of very low legume content so there will not be a strong bank of soil nitrogen for the grass seedlings to access. After establishment, either N fertiliser or a strong companion legume will be needed if these grasses are to perform anywhere near their potential.

In practice, fertiliser applications on saline sites are often overlooked, as placing expensive inputs onto lowly productive sites can be poor economics.

GRAZING OPTIONS AND MANAGEMENT

Well-researched grazing management guidelines are available for the subtropical grasses[65] because of their widespread use in non-saline grazing systems. With a little adjustment to account for the fragile nature of many saline sites, these same principles can be applied to saltland situations. The general rules for grazing subtropical grasses, modified for saltland situations include:

- Careful grazing is needed during the establishment year as Rhodes grass in particular is susceptible to being pulled out by grazing livestock. Keeping the grazing pressure low will also allow these species to spread vegetatively and thicken up the stand if establishment has been less than ideal.

- Grazing over winter will be minimal if the subtropical grasses are the main pasture species as growth will be virtually non-existent, but also because most saline sites are waterlogged to some degree over winter and early spring and can be highly susceptible to pugging damage.
- Once firmly established, the grazing requirements for kikuyu and Rhodes grass are quite different.
- Kikuyu is highly suited to heavy grazing, either via continuous stocking or short rotations. The underground or surface stolons are very resistant to being pulled up by grazing animals, and if not grazed heavily, a heavy mat of unpalatable stolons will develop and smoother all competitive or companion species. The problem is that the soils on most saline sites cannot stand such heavy grazing pressure, and neither can most of the other species that might be sown on a saline site in the more salty areas where kikuyu will not have colonised, and where the soils are likely to be even more fragile. Finding a grazing compromise in these situations can be difficult. Because there are usually environmental and amenity benefits being sought from saltland pastures, the grazing management is likely to be more conservative than for similar pastures on non-saline land. For kikuyu, this will mostly mean it is not grazed frequently enough or heavily enough to keep its feed quality high.
- The grazing management recommendations for Rhodes grass are more similar to the temperate perennial pasture grasses than kikuyu. Once established, and especially in reasonably fertile situations, Rhodes grass can be set-stocked as long as the stocking rate is not so high that the stolons get pulled out by the grazing animals. This is a particular problem on light soils. Rhodes grass is very suited to rotational grazing and such an approach is much more likely on saline sites where maintaining groundcover is at least as important as forage production for livestock.
- For both kikuyu and Rhodes grass, grass dominance is encouraged by the sort of undergrazing that is often preferred on fragile, saline sites. This makes it doubly difficult for legumes to make a significant contribution to the pasture in saline situations as they struggle with both the salinity and the highly competitive grasses.
- For both kikuyu and Rhodes grass, the stands thin out, they can be thickened up by spelling for a growing season, and this thickening up will be assisted by fertiliser application.

ANIMAL NUTRITION ISSUES

Both sheep and cattle will perform well on these subtropical grasses if the sward is kept vegetative. For kikuyu and Rhodes grass, typically the growing leaves would have a digestibility in the low 60%s (ME of ~9 MJ/ kg dry matter) but the stems are much less digestible – say 6-7 MJ/ kg.

There have been some rare reports of kikuyu poisoning in New Zealand, Queensland, New South Wales and Western Australia. It is an unusual disorder, but occurs sporadically in cattle. In most cases, the outbreaks have followed the introduction of livestock to paddocks that had been spelled for a period and which had become quite lush or rank. It can also occur in pasture that receives good summer rain after being fertilised, and is growing vigorously.

It is unlike to be a problem in situations where kikuyu makes up only part of the suite of species growing at the different salinity and waterlogging levels across a saline site which has been sown to a shotgun mix.

SUPPORTING RESOURCES

Barrett-Lennard, Ed. *Saltland Pastures in Australia – a practical guide*. Available from http://www.landwaterwool.gov.au/products/pr030563.

Masters, David G., Benes, Sharon E., Norman, Hayley C. (2007). Biosaline agriculture for forage and livestock production. *Agriculture, Ecosystems and Environment* **119**, 234–248.

WA Department of agriculture and food Farmnotes http://www.dpi.nsw.gov.au/aboutus/resources/factsheets/agfacts_and_agnotes Summer Growing Perennial Grasses in the Central Swan Coastal Plain and Hills Region.

The *National Dryland Salinity* Program (NDSP 1993–2003) was the first national attempt to better understand the causes, impacts, costs and management options for preventing and/or overcoming dryland salinity. The final year of the program was dedicated to harvesting the knowledge and making it available to the diverse range of stakeholders through the Managing Dryland Salinity in Australia resource kit. http://www.ndsp.gov.au/. An update was published by Land & Water Australia in 2006. http://www.lwa.gov.au/.

Saltland Solution 10

Legumes for saltland

IN A NUTSHELL

Clovers and medics underpin most Australian improved pastures on non-saline land, not only for their significant contribution to animal nutrition, but also on account of the nitrogen they are able to fix from the atmosphere which later becomes available to grasses. Unfortunately, subterranean clover, the most commonly sown pasture legume in southern Australia, has very low salt tolerance, and is among the first pasture species to disappear with the encroachment of salinity. Similarly, white clover, the most important clover species worldwide and important in the high rainfall zone and for irrigated pastures, is very susceptible to salinity.

Legumes are usually much less salt-tolerant than grasses, apparently due to their relative inability to exclude the toxic salts (ions) that disturb enzyme activity once taken up into the plant.

Furthermore, for legumes to achieve their potential they must fix nitrogen, which means that not only does the legume need to be able to tolerate salinity, but that a salt-tolerant rhizobia is also needed, Finally, a 'salt-tolerant' symbiotic relationship between the legume and the rhizobia must be able to form in the hostile environment of a saline soil. These three quite significant challenges need to be overcome simultaneously and in most cases this has not happened. A robust salt-tolerant legume is something of a 'holy grail' for graziers with saltland and for researchers. It is still some distance away but there are options for areas of mild salinity.

As a general guide, the most common legume species for saltland are (ranked from most to least salt- tolerant) burr medic, lucerne, strawberry clover and balansa clover. However this ranking is only meaningful when set alongside waterlogging tolerance, which will often eliminate lucerne and burr medic from the choices. *Melilotus* species, some of which have high levels of salt- and waterlogging-tolerance, are currently limited by the lack of salt-tolerant symbiotic rhizobia.

Balansa is highly waterlogging-tolerant so if established after flushing autumn rains it can experience quite low surface soil salinity and early flowering cultivars can set seed and avoid the high salinity levels over summer.[66] Lucerne is widely used in salinity management across southern Australia to reduce recharge, and is often sown around saltland to reduce local upward pressure from the watertable and thereby reduce discharge onto the saline site. However it is not well suited to saltland itself, having only a moderate tolerance for salinity and low tolerance for waterlogging.[66]

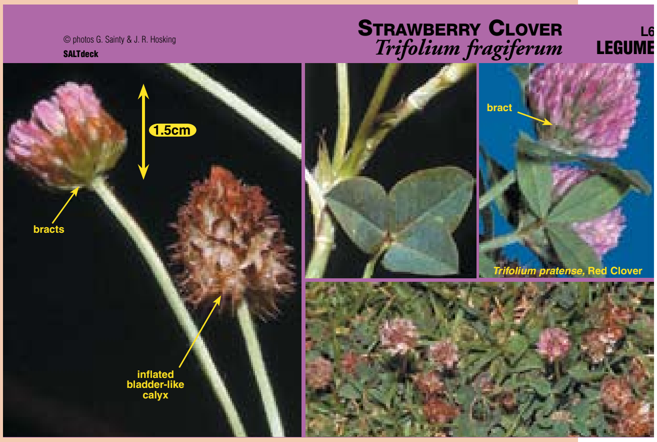
Because legumes have only limited tolerance to salinity, in most saltland pasture situations, the critical component is the salt-tolerant grass or shrub. The key decisions relate to which grass, shrub or mixture is the most appropriate for the particular saltland site. Legumes are included in the seeding mix to take advantage of less saline areas where they can establish and make a significant contribution to pasture quality and/or soil nitrogen.

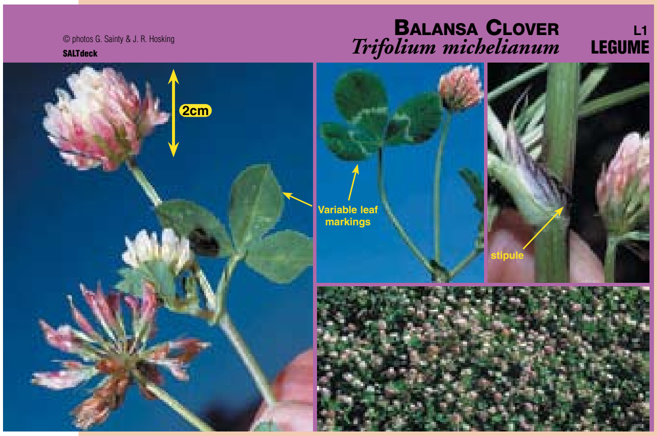
South Australian, Western Australian and Victorian researchers over the past 15 years have investigated the performance of a wide array of pasture legumes under both field and glasshouse conditions. They found that of the commercially available pasture legumes, strawberry clover (*Trifolium fragiferum*), balansa clover (*T. michelianum*) and Persian clover (*T. resupinatum*) were the best options for salt-affected land prone to waterlogging, while burr medic (*Medicago polymorpha*) and to a lesser extent barrel medic (*M. truncatula*) and lucerne were best suited to saltland not subject to waterlogging. However even these species were still relatively salt-sensitive and persisted in only low to moderate levels of soil salinity.[67]

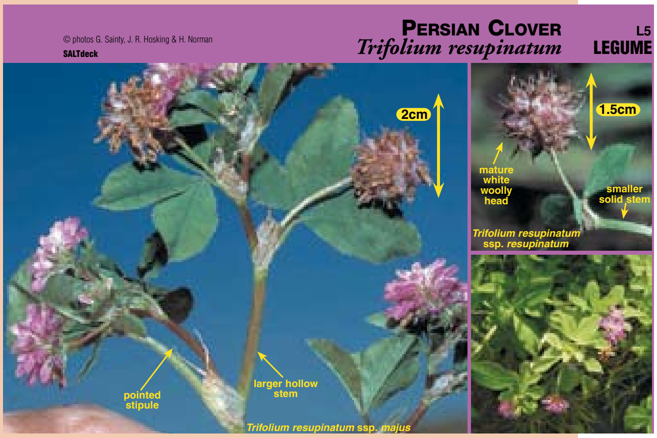
Since the mid-1990s there has been considerable research interest in the suitability of *Melilotus* species to saline conditions in southern Australia., particularly *M. albus* and more recently *M. siculus* (sometimes referred to as *M. messanensis*). The *Melilotus* species have generally shown superior levels of salt tolerance combined with good dry matter production compared with both balansa and strawberry clover, apparently due

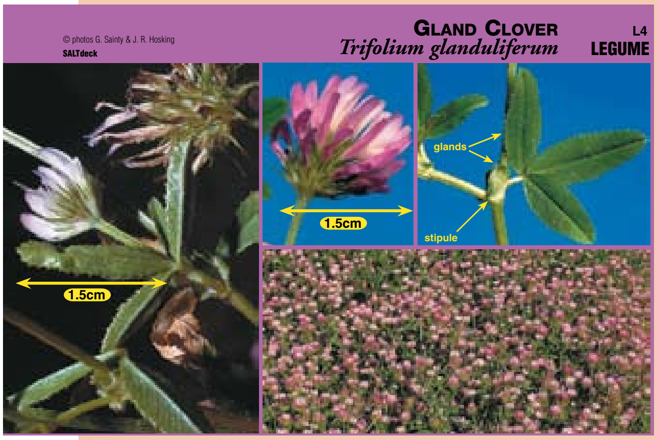
SPECIES IDENTIFICATION

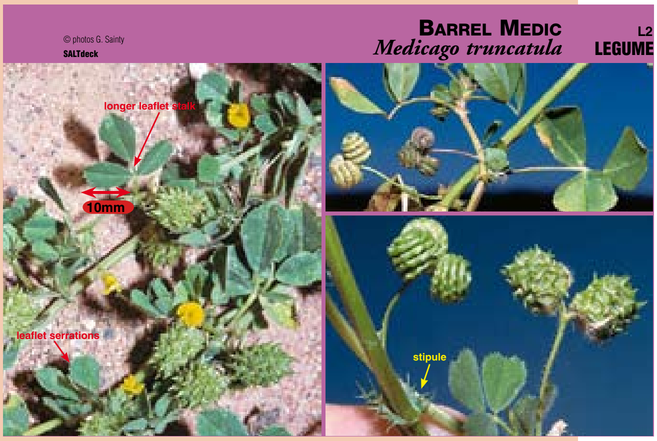
Figure SS10.1: SALTdeck card to assist with the identification of balansa clover.
Figure SS10.2: SALTdeck card to assist with the identification of gland clover.
Figure SS10.3: SALTdeck card to assist with the identification of woolly clover.
Figure SS10.4: SALTdeck card to assist with the identification of strawberry clover.
Figure SS10.5: SALTdeck card to assist with the identification of Persian clover.
Figure SS10.6: SALTdeck card to assist with the identification barrel medic.
Figure SS10.7: SALTdeck card to assist with the identification of burr medic.

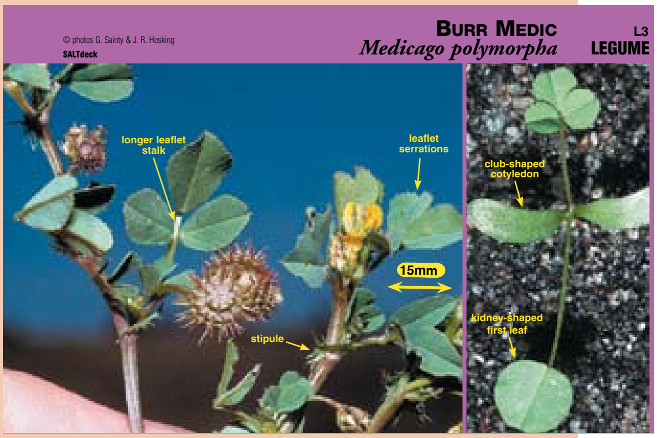












to their ability to exclude sodium and chloride from their roots.[67]

Jota, the first cultivar of annual *Melilotus albus* commercially released in Australia by the National Annual Pasture Legume Improvement Program, is intended for neutral to alkaline soils where it can be used as a companion legume for tall wheatgrass. It has higher salinity tolerance than other commercial legumes, but has poor waterlogging tolerance. In Western Victoria it has performed very well on raised beds. A potential concern with this species is its relatively high coumarin levels, which could lead to a haemorrhagic condition in livestock under some conditions. The target area has saline soils receiving more than 500 mm of annual rainfall and a soil pH of 6 or higher – at this stage it is not recommended in WA because of its high coumarin levels.

Lucerne is usually thought of in terms of recharge reduction rather than discharge management, but it is one of the more salt-tolerant of the perennial legumes. However, its susceptibility to waterlogging precludes its use on many saline environments.[67]

In the late 1990s a commercial cultivar, Salado, was released with a reputation of being a more salt-tolerant lucerne. It was hoped that Salado could be used as a salinity management tool, resulting in reclamation of saltland and improved farm profitability and sustainability. Salado was the result of more than 15 years of selection, not only for germination, but in combination with establishment, vigour, and forage yield under saline conditions. Although quite widely trialled by farmers in Australia, it has not shown advantages over other lucernes on saline soils.

MOST LIKELY SITUATIONS

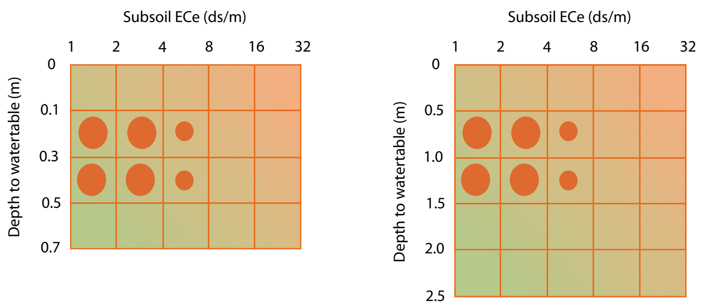
LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions, and management) where they are most competitive or where they will perform best. Saltland plants are the same, each tending to have a particular set of climatic (rainfall, temperature etc) and soil (salinity, waterlogging) factors which determine where they will be able to survive, and where they are likely to thrive. For saltland legumes, these factors are summarised below.

10 – MOST LIKELY SITUATIONS FOR SALTLAND LEGUMES

SUBSOIL SALINITY/ DEPTH TO WATERTABLE MATRIX

WINTER | SUMMER



DRIVERS OF PLANT ZONATION

- Low salinity tolerance
- Non-halophytes and very limited to salinity tolerance
- Some are sensitive to waterlogging, others thrive
- Annuals more promising than perennials
- Re-establishment of annual legumes an additional challenge
- Rainfall >300 mm

Key to symbols

● *This is the zone most preferred by saltland legumes and where they are highly recommended for inclusion in saltland pastures.*

• *Saltland legumes in a pasture mix is one of the possible options for this zone, but it is outside their preferred conditions.*

COMMON INDICATOR SPECIES

Balansa and strawberry clovers and melilotus species thrive in conditions with winter waterlogging but only moderate levels of salinity. In addition, strawberry clover needs summer moisture to survive as a perennial. These are conditions that often favour buck's horn plantain, Yorkshire fog, toad rush and spiny rush.[68] These legumes will not grow in saltier environments where more salt- tolerant species dominate.

The legumes that can tolerate low to moderate salinity (burr medic and lucerne) cannot tolerate waterlogging – conditions that are more suited to barley grass, annual ryegrass, prairie grass or windmill grass.[68]

SOIL AND CLIMATE REQUIREMENTS

Table SS10.1 shows the minimum rainfall requirements for the main salt-tolerant legumes, and soil salinity and pH levels beyond which productivity is compromised. These figures are a guide only, as seasonal rainfall distribution, maximum temperatures, soil types, and topography will all be important influences. For annual pasture legumes, the critical site salinity measurement is in the surface 10 cm during early autumn, reflecting the highest levels of salinity that the regenerating pasture seeds might be subjected to at germination. It is more difficult to prescribe the optimal time and soil depth for determining perennial plant suitability on saltland.

Because salinity is often associated with waterlogging, it is generally more meaningful to consider not just salt tolerance but saltland capability which takes account of both constraints.

Despite limited options, most saline areas have access to at least one well-adapted pasture grass, which can form the basis of a productive pasture, and sometimes there are legumes that can form part of that pasture across some of the less saline parts of the site.

WATERLOGGING AND SURFACE WATER MANAGEMENT

There are no general rules for the management of surface water for legumes on saltland. Balansa, Persian and strawberry clovers are highly tolerant of waterlogging and inundation, provided some of the plant is above the water level. Burr medic, lucerne and *Melilotus albus* are quite the opposite and do not tolerate prolonged waterlogging.

Surface drainage can be of value in allowing initial access to the site for establishing the pasture whether the individual species are waterlogging tolerant or not. Deeper groundwater drains may prove to be a disadvantage to strawberry clover, potentially depriving the pasture of moisture in early summer, but reducing the risk of waterlogging could also open up opportunities for lucerne. Such drains present legal challenges in many jurisdictions and local advice should be sought.

Plants in low or summer-dominant rainfall regions are generally less at risk of waterlogging stress than plants in high rainfall areas of southern Australia, which might spend months in waterlogged conditions through winter. Research conducted at Tamworth has shown that lucerne in particular can be significantly more productive on saltland when waterlogging is not an issue.

Table SS10.1: Rainfall and salinity levels for different legume species and varieties.

	Paradana balansa	Bolta balansa	Frontier balansa	Persian clovers	Palestine strawberry clover	Lucerne	Burr medic	Melilotus albus
Annual rainfall	450-700	> 600	350-500	>600	> 600	>325	325-450	> 500
Soil salinity tolerance levels EC_e (dS/m) prior to break of season	< 8	< 8	< 8	< 8	< 8	< 9	< 10	<10
Soil pH ($CaCl_2$)	4.5-8.0	4.5-8.0	4.5-8.0	5.0-8.0	5.5-9.0	>5.6	5.2-8.5	>5.6

THE BENEFITS

PRODUCTION

The contribution of legumes to the productivity of pastures is well known and documented – they have higher protein content and digestibility than grasses, and they increase soil nitrogen levels for the benefit of grasses. Similar benefits could be expected from legumes in saltland pastures.

The challenge is to find and manage legumes that can cope with an environment to which they are typically unsuited. It is difficult to make general claims about the production benefits of most plants growing on saltland, and even more so with the legumes that are relatively sensitive to these conditions. In practice, there are few saline pastures across southern Australia where legumes make the sort of contribution that would be expected on non-saline sites.

Tall wheatgrass (in higher rainfall zones) and saltbush (in lower rainfall zones) have some ability to locally lower the saline watertable and therefore provide a more hospitable environment for companion legumes. It has certainly been shown that when effectively managed, tall wheatgrass pastures sown with companion legumes are capable of increasing stocking rates quite dramatically.[69]

SGSL research at Mt Charles in the Upper South East of South Australia has quantified the benefits of integrating balansa clover with well managed puccinellia pasture. The addition of balansa clover into the pasture resulted in a further 24% increase in per hectare animal performance.[69]

The dry matter production and nutritive value of saltbush is generally not sufficient by itself to cover establishment costs, but introducing higher quality pasture plants in the inter-row, such as burr medics and balansa clover, can dramatically tip the balance. The role of the saltbush is then partly to provide a more hospitable site for the legumes which are relatively salt-sensitive.[69]

Research in WA by the CRC Salinity has shown that burr medics persist and produce more feed over three or more years than balansa and Persian clovers on low rainfall (<400 mm), moderately saline land with little or no waterlogging. Similar results were also found in the summer-dominant rainfall regions of northern NSW on sites not subject to waterlogging.

In northern NSW research by the CRC Salinity found that lucerne out-performed strawberry clover and other prospective perennial legumes in terms of both herbage production and persistence on saltland over four years from establishment. However, it should be noted that this research was carried out during an unusually dry period for the region, with a lower incidence of waterlogging than normal.

In southern regions with winter dominant rainfall the performance of commercially available perennial legumes on saltland subject to waterlogging is not encouraging. Limited production and poor persistence, particularly over long hot summers, to some extent mirrors the situation for non-saline land – but more so.

Overall, a mix of grasses, legumes, shrubs and forbs is likely to maximise the feeding value of saltland pasture, allowing grazing animals to select specific plants for a balanced diet. The legumes also help improve the growing conditions and dry matter production of the other pasture plants.

WATER USE

Annual legumes are generally shallow-rooted and do not contribute significantly to water use on discharge sites. However, complementary perennial grasses and shrubs that are often sown with these legumes can help relieve sites of waterlogging.

The ability of tall wheatgrass and saltbush to use water throughout summer means that the soil needs more water to become saturated following the autumn break. This delays the onset of winter waterlogging under tall wheatgrass pastures which may include other species such as balansa clover, or in saltbush pastures that may contain a mixture of under-storey grasses and legumes. Monitoring of a site in the Great Southern Region of WA showed that winter waterlogging occurred a month later on tall wheatgrass-balansa pasture compared to balansa-only pasture. The duration of waterlogging on tall wheatgrass-balansa pastures was also reduced to a third of the time that the balansa-only pasture was waterlogged during a growing season (May – October).

Lucerne is renowned for its ability to intercept recharge and can perform this role on some discharge sites, provided the site is free from the risk of waterlogging. In summer rainfall situations lucerne can be productive at salinities of up to EC_e ~8 dS/m, in the process reducing recharge. In southern Australia, the opportunities to use lucerne in this way are limited. However, farmers in South Australia have demonstrated very good results where the risk of waterlogging has been reduced with well planned drainage and drier years.

In summary, legumes can be expected to contribute very little to water use on saline sites, but can benefit substantially if other species use a lot of water and reduce the waterlogging incidence. Lucerne has a major ability to use water on or around saline sites, provided the water is non or mildly saline and there is little or no waterlogging.

AMENITY AND ENVIRONMENTAL

Improved visual amenity is a strong motivator for most farmers who are actively involved in revegetating saltland. Under suitable conditions (low to moderate salinity and waterlogging), saltland pastures can transform a salt-affected site otherwise supporting only sparse sea barleygrass, and sometimes, legumes can be a significant contributor to such a pasture.

In terms of biodiversity value, SGSL research showed that mixed species pastures are intermediate between bare salt scalds and remnant native vegetation as measured by Landscape Functional Analysis and therefore represent a 'win:win' situation, with better production and environmental outcomes compared to untreated saline areas.

The above conclusions are about saltland pastures in general, and not about legumes in particular. It would be rare for legumes to be included in a saltland pasture mixture for their contribution to amenity or environmental values. The pasture might be primarily established for that purpose, but the inclusion of a legume will be primarily to increase pasture production and animal nutrition. The exception might be that if legumes disappear from a pasture because of salinity, waterlogging or poor pasture management, it is reasonable to expect that their place will be taken by weeds or bare ground.

HOW THE $$$s STACK UP

The profitability of legumes on saltland is generally not separated out from the profitability of complementary grasses or shrubs in the pasture – rarely will a legume be sown as a single species in saline conditions.

Given that legumes are considerably less tolerant of salinity and/or waterlogging than grasses and shrubs, they really only represent an economic opportunity on higher capability land. Farmer case studies looking at the potential for profitable use of legumes on salt-affected land can be found on the Saltland Genie website.[70]

Geoff Aurricht (SARDI) inspecting lucerne cultivar. Photo: G. Auricht

ESTABLISHMENT AND MANAGEMENT

CHOOSING THE RIGHT SPECIES AND VARIETIES

Companion legumes play an important role in the continued vigour of grassy pastures, on saline or non-saline land. However, the reality for any land with more than mild salinity is that legumes will play only a minor role in the pasture and ongoing nitrogen deficiency will be common. The applicability of legumes needs to be assessed on a site-by-site basis as salinity levels, risk of waterlogging, soil pH and seasonal rainfall will all influence the appropriate choice.

Local experience of which legumes have the best chance of making a significant contribution should be sought from technical experts, extension providers and other farmers.

The annual Balansa and Persian clovers are generally compatible with tall wheatgrass on mildly saline sites. Balansa is particularly adaptable to waterlogging, but neither regenerate well in moderately saline conditions – the clover will often perform well in the year of sowing, but fail to reappear the following year.

The annual clovers are often best direct-drilled the year after tall wheatgrass or puccinellia establishment to ensure the perennial grasses have established well before the more vigorous annuals are introduced – there is a hierarchy of importance, with the grasses 'essential' for a long-term pasture, and the legumes 'desirable'. Similarly, these clovers can be direct drilled into established stands of puccinellia (in particular) or tall wheatgrass (more difficult because of its clumpy nature) to give them what often turns out to be a one-year clover and soil nitrogen boost.

Strawberry clover can be a useful companion legume with tall wheatgrass in long growing season areas, but it has a dislike for highly acid soils.

Lucerne can be established on land with low to moderate salinity if there is only limited risk of waterlogging. From this viewpoint it is well suited to land that has been protected by adequate surface drainage. Like strawberry clover, it is sensitive to highly acid soils. In reality, the most important role for lucerne in dryland salinity is in reducing recharge because of its deep rooting and its ability to use large amounts of soil water. This may be 'upslope', or around the edges of saline areas.

Burr medic is suitable for moderately saline soils, but like lucerne it is intolerant of prolonged waterlogging.

SITE PREPARATION

While not 'legume specific', the following steps are all important prior to the sowing of a saltland pasture.

Fencing to control grazing pressure is required, as pasture is often sown into soil that soon becomes wet and vulnerable to pugging by livestock. Temporary electric fencing may be sufficient, particularly for small areas where separate grazing is impractical.

Remove excess water if waterlogging is likely to be a problem at sowing. Diversion or reverse interceptor banks can reduce the movement of runoff water onto the area, (take care that these banks do not go through sodic soil that might give way and lead to erosion), or shallow drains can assist the movement of surface water off the site. When designing drainage systems it is important (and possibly a legal requirement) to consider the impact of disposal on downstream biodiversity and landholders and ensure there will be no harm done.[71]

Control weeds (especially the annual grasses such as sea barleygrass), by spray topping the previous spring. It may still be necessary to kill germinating weeds prior to sowing with a knockdown herbicide.

Take a soil sample (top 10 cm) and get it tested for salinity and major nutrients. It may be prudent to also test for salinity at depths greater than 10 cm, particularly as legumes tend to be more salt-sensitive than the companion grass or shrub.

Lightly cultivate or scarify the soil prior to the break of the season (if planning some leaching of salt with the opening rains. With both cultivation and herbicide use, the time without vegetation should be minimised to reduce the capillary rise of salts to the surface.

WEED AND PEST CONTROL

The main weeds at sites where legumes are likely to make a contribution are capeweed and annual grasses such as sea barleygrass. These should be sprayed in the spring before sowing to reduce the seedbank. Annual legumes might have to be sown a year after perennial grasses such as tall wheatgrass or buckshorn plantain, because the annuals' vigour can suppress growth of the tall grass seedlings, particularly on areas of mild salinity.

Red-legged earth mite (RLEM) is a significant threat to all legumes, particularly as young seedlings, and must be controlled during pasture establishment.

Bare earth treatment with bifenthrin (Talstar®) immediately following sowing is likely to control RLEM for up to five weeks to allow successful establishment. Pastures should be monitored for signs of RLEM, lucerne flea and aphids in spring and in subsequent seasons and controlled with appropriate insecticides if necessary. This approach used regularly in the same paddock could lead to pesticide resistance, but this is unlikely in a grazing situation.

Seed can be treated with omethoate, but this provides only limited protection, albeit at the very critical time immediately following germination.

Timerite® is an online tool developed by Australian Wool Innovation and CSIRO that provides the optimal spray date for the effective control of RLEM for your local area, thereby reducing the risk of carryover to following years. By spraying on your Timerite® date in spring, optimal control is achieved in the following autumn when annual legumes are most susceptible.

SOWING

Pasture mixes

Balansa clover, strawberry clover, Persian clover, *Melilotus albus* and lucerne are all generally sown on saltland in combination with a grasses such as tall wheatgrass, puccinellia, tall fescue/phalaris or subtropical grasses. Balansa clover, sub clover and burr medic are often included in a saltbush under-storey, shotgun mix including annual and sometimes perennial grasses. The grasses help to balance the pasture by extending the grazing season and taking advantage of variations in soil condition across the paddock. The legumes contribute valuable nitrogen to the grasses and protein to the grazing animals.

Typical recommended mixes for high rainfall areas (e.g. >500 mm) include:

- EC_e: <5 dS/m: TWG, tall fescue*, strawberry and balansa clovers**.
- EC_e: 5-10 dS/m: TWG, strawberry and balansa clovers.

For lower rainfall areas a typical mixture would comprise burr medics and balansa clover. Barrel medic could be included for alkaline soils.

** Victorian trials have shown that Resolute and Advance tall fescue will germinate and grow at EC_e levels up to approximately 8 dS/m, losing up to 50% of productivity at this higher salinity level.*

*** The early-flowering Frontier balansa has the advantage that it can set seed before salinity levels escalate in spring.*

Under favourable conditions balansa and Persian clover will out-compete young tall wheatgrass seedlings, particularly as sowing after an opening rain has flushed some salt from the topsoil. These clovers are not particularly salt-tolerant and this initial flushing of salt greatly enhances their dominance. Therefore, under low salinity conditions, balansa clover is often not sown with wheatgrass in the first year, but rather a year or two later.

Seeding rates

A typical pasture mix with legumes on a mildly saline site might include 4-5 kg/ha tall wheatgrass with medics at 2 kg/ha, clovers at 0.5-2 kg/ha, lucerne at 2 kg/ha and phalaris at 2 kg/ha. However, the best local mix might contain subtropical as well as temperate grasses and in drier regions it is likely that saltbush will be in the mix, possibly replacing all the perennial grasses. It should be noted that subtropical grasses and saltbush require spring sowing, whereas the optimum sowing time for the other species is in autumn.

If legumes are to be sown the year following the wheatgrass, the latter should be sown at the lower rate suggested for mixed species. However this can lead to weed invasion while the grass is thickening up.

Establishment costs for a mixed pasture are about $300/ha for seed, cultivation, herbicide and fertiliser, plus a further cost for fencing which will depend very much on the size of the saline area. In addition there is the opportunity cost associated with the establishment downtime, but in most cases the opportunity foregone on unimproved saltland is very small.

Because of the large number of possible combinations, it is best to seek local advice regarding both species and cultivars to include, and the rates for the individual species. Legumes must have a suitable rhizobium to enable nitrogen fixation – as saltland has often not carried legumes before, or at least not for a long time, it will generally be important to inoculate the seed before sowing.

Time of sowing

Options for sowing times are largely dependent on weather condition and the state of the paddock.

Many of the difficulties in establishing legumes are similar to those associated with other pasture species on saline sites. Because many saline sites are waterlogged for significant periods, there is often only a small window of opportunity to control weeds and sow the pasture.

If possible, seeding should be done following good opening rains that are sufficient to flush salts from the soil surface. The seedling and early establishment stages are very susceptible to salinity. Dry sowing should be avoided, particularly in unreliable rainfall areas, as the opening rains may be sufficient to germinate seeds, but insufficient to flush salts from the surface, causing major seedling losses. It also reduces the opportunity for weed control. In many areas, this may mean a very narrow sowing window, as areas prone to waterlogging may get too wet for sowing very quickly.

The best options are:

- Autumn sowing after the autumn break (in southern Victoria, before the end of April).
- Spring sowing, as soon as the area is trafficable after the end of winter. This option is only feasible in areas with reliable spring rainfall and works well in years with dry winters. However, if the area is not trafficable until late spring, there will be insufficient time for the plants to establish before the onset of higher salinity levels in summer. Sowing in spring is of course not an option if an annual such as balansa clover or burr medics are to be included.

MANAGING NEW STANDS

Year 1

Balansa or Persian clover as a companion in tall wheatgrass or puccinellia pastures might be avoided in the first year as their vigour can suppress the grass. However, if balansa or Persian clovers are sown, stock should be removed in time to allow the clover to flower and set seed. This conflicts with the need to maintain grazing pressure on grasses such as tall wheatgrass to ensure it remains vegetative, so when seed-set is complete, crash grazing is recommended to bring the pasture down to a uniform stubble of about 10 cm. Removing the excess growth will help control weeds, encourage better leaf growth and make grazing management over summer much easier.

In lower rainfall areas, where burr medics are likely to be the dominant sown legume, grazing pressure should be markedly reduced during flowering and seed set to maximise seed production and persistence. This is also the best management for balansa or Persian clovers, if they are included in mixtures.

Grazing over summer-autumn should be conservative, aimed mainly at maximising pasture persistence, rather than maximising immediate production. For perennial grass-based pastures grazing down to about 5 cm will promote strong root development. Removal of excess thatch and legume stubble is required to enable adequate hardseed breakdown of annual legumes and provides good conditions for regeneration with opening rains.

Year 2 and thereafter

Annual legumes (balansa and Persian clovers, burr medics) survive saline conditions essentially by not growing over summer when saline conditions are usually the most severe – the challenge for these annual legumes is to ensure regeneration in subsequent years. To make this strategy successful, annual legumes need to mature early enough that they can set seed for following years before salinity levels in the soil build up in spring. They also need to produce sufficient hard seed (that maintains its hardness) to ensure survival of the pasture despite a possible false break in year two.

The burr medics, particularly Scimitar, are early flowering and produce a relatively high proportion of hard seeds. This gives them a major advantage over other legumes in low rainfall areas. For Balansa clovers, Frontier matures 2-3 weeks before Paradana and about five weeks before Bolta. This means that Frontier can set seed in many environments before salinity levels increase in spring, while Paradana and Bolta are only able to set seed in very long growing season areas. Newer Persian clovers, including Nitro Plus, Persian Prolific and SARDI Persian are earlier flowering than older cultivars, but are not as early flowering as Frontier. Jota *Melilotus albus* is very late flowering and will only set seed in very long growing season areas.

Annual legumes face two significant challenges every year. Firstly they have to set viable seed in the spring when soil salinity levels can be rising rapidly. Secondly, if they attempt to germinate with the opening rains, there is a serious risk that soil salinity levels will be too high for the germinating seedlings. Later in the season, the winter rains will have flushed the salt from the surface soil, making it more suitable for germinating legume seedlings, but by then, other annual species and the growing perennials will have occupied the seedling niches. The result is that many annuals produce very poorly in their second and following years. Research is being conducted to understand seedling interactions with soil surface salinity and rainfall to enable development of legumes better able to resolve this issue.

Perennials such as strawberry clover and lucerne only need to be established once, but like the annuals, they need an appropriate inoculant to ensure the nitrogen fixing potential of the plant. An additional constraint is that unlike annuals, they do not set seed and die off to avoid the often very high summer soil salinity levels.

The main risk to perennial pasture species is always over grazing, generally as a consequence of set stocking. Grazing management of mixed pastures will need to be carefully considered where pasture species have different seasonal growth patterns. Allowing seed set for legumes whilst preventing loss of pasture quality through rank growth of perennial grasses, such as tall wheatgrass, involves compromises which can cause deterioration of the pasture. For saltland which is more fragile than normal land, some form of rotational grazing is recommended – it is usual to leave a greater residual (i.e. the pasture left in the paddock when the stock are withdrawn) than for non-saline pastures so that groundcover is kept high and surface soil evaporation is kept low. The grazing management system must also account for the needs of the various pasture components – aerial seeding species such as balansa clover and burr medics need to have minimal grazing during flowering and seed set. Once annual legume seed set is complete (which depends on the cultivar) the stand can be crash grazed to remove excess growth and grass stems, which will have started to run up to flower.

A soil test every 3-5 years will help determine fertiliser requirements, but this also should be balanced against cost-effectiveness and the purpose of the pasture.

Continue grazing throughout summer and into autumn to maintain a pasture height below 10 cm. Stock will avoid grass that has begun to go rank, exacerbating the problem of selective grazing, in which case it might be necessary to increase the stocking rate or set up electric fences to force grazing.

REJUVENATING OLD SALTLAND PASTURES

Most old stands of salt-tolerant pasture have little or no legume component. Where salinity levels allow, balansa clover seed can be broadcast with the fertiliser in early autumn. If soil conditions permit, and if rank grass is removed and some bare ground is visible between plants, balansa clover will readily germinate.

ANIMAL NUTRITION ISSUES

Overall, legumes in saltland pastures make a significant contribution to animal nutrition because of their high protein content, their high digestibility compared to other pasture species, and because they do not accumulate salt.

An exception to the nutritive excellence of legumes is bloat – though saltland pastures with sufficient legume content to cause bloat are extremely rare. However, animals grazing saltbush-based or tall wheatgrass-based pastures usually graze the 'other' pasture species first and therefore might obtain a diet high in legumes when first introduced into the paddock. Also, any non-saline land within the fenced saltland paddock may contain a high legume content and be grazed preferentially.

There are some potential animal health concerns with Jota *Melilotus albus*, particularly if it is used to make silage. *M. albus* contains relatively high levels of chemical compounds called coumarins, which can be converted into a compound (dicoumarol) that can cause haemorrhaging in livestock when fermented silage is fed in large quantities. Although Jota has been selected as a cultivar with lower coumarin contents than other *M. albus* types, its levels are still higher than other pasture legumes. However, the risk will be reduced if animals also have access to other feed sources (live plants or supplements) to dilute possible effects.

SUPPORTING RESOURCES

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Saltland Solution 11

Revegetating – non-grazing options

IN A NUTSHELL

This saltland solution focuses on two main strategies:

- Revegetating with trees, shrubs and/or under-storey with the selection of revegetation species focused on conservation and visual amenity, with no aspirations for a commercial product.
- Revegetating with trees, with the species selected for commercial wood products such as saw logs, pulp and firewood.

Most trees are not halophytes (salt-loving plants), so saltland inevitably provides a hostile environment, especially if combined with waterlogging. Part of the appeal of agro-forestry or woodlots with salt- tolerant trees over shallow watertables is the opportunity for these to access abundant water. However there is a question mark over the sustainability of this enterprise if it leads to accumulation of salt in the root zone.

Notwithstanding this, considerable research has been directed towards identifying salt- and waterlogging-tolerant tree species and developing particularly tolerant hybrids and cultivars.

An upside of growing trees on land of low to moderate salinity is that it is a low maintenance option which can be suitable for areas that might be too small to manage for grazing or that do not have a water supply for livestock. It can also offer side benefits of reducing saline runoff from waterlogged sites and provide strategic shelter for livestock, such as sheep off shears.

The current interest in planting trees for greenhouse gas abatement may add significantly to the motivation for establishing trees. This could be particularly attractive for saltland which apart from grazing, has few other prospects for productive use.

There are significant hurdles for saline forestry. The most important commercial eucalypts and *Pinus radiata* do not grow at all well on saltland, and since dryland salinity is most commonly found in the 400-650 mm rainfall zone, which is typically more than 100 km from coastal ports, there is little commercial prospect for short-rotation pulpwood. Instead, trees have mainly been grown for firewood, honey or for on-farm use such as fence posts.

Despite these challenges, there has been considerable interest in enhancing the value of salt-tolerant trees by developing pulpwood and/or sawlog species. This has been particularly the case for irrigation areas where rising saline groundwater threatens high value crops, and where salt-tolerant trees can both reduce recharge and tap directly into the watertable.

Water pumped from saline aquifers or from wastewater treatment plants is also applied to salt-tolerant trees which act as a sump but also provide the opportunity for a commercial return from the product. This latter application has been a significant driver for the development of more salt-tolerant commercial varieties.[72]

MOST LIKELY SITUATIONS

LANDSCAPE NICHE

All plants have landscape niches or zones (combinations of climatic and soil conditions and management) where they are most competitive or perform best. Saltland plants are the same, each tending to have a particular mix of salinity and waterlogging which determine where they will be able to survive, and are likely to thrive.

This concept is used in the other Saltland Solutions to identify the niche where a particular saltland species is most likely to be suited. However, for this Saltland Solution it is not possible to nominate a 'suitable' mix of salinity and waterlogging because the species established in a non-grazing situation will be selected specifically to suit the particular salinity and waterlogging situation.

Sites that might be suitable for trees are typically characterised by salt-tolerant grasses of the medium to high rainfall zone such as barleygrass, Yorkshire fog, prairie grass or annual ryegrass and perhaps sea barleygrass, although the latter tends to colonise land too salty for most trees.

Mature trees generally have much deeper root systems than grasses and can be more susceptible to sudden rises in watertable and soil salinity because their root systems cannot adjust quickly. This makes it difficult to relate visual attributes such as indicator plants or soil surface conditions to the prospects for tree crops.

Where trees are to be used for the disposal of pumped saline groundwater, the site characteristics will be largely dictated by the location of the wastewater. Generally, sandy soils are best suited for disposal of moderately saline water as this allows leaching of salts from beneath the root zone. On the other hand, moderately saline water can improve structural problems associated with sodic soils.

SOIL AND CLIMATE REQUIREMENTS

Successful farm forestry enterprises are most commonly found where annual average rainfall exceeds 600 mm. However, trees grown on saltland often have the advantage of access to a shallow, albeit salty, watertable. The limiting factor then is more likely to be levels of salinity and waterlogging rather than the availability of soil moisture. However, salt-tolerant trees may lower watertables locally by reducing recharge and drawing on groundwater so much over a number of years that lack of soil moisture could eventually become an issue as the trees mature.

Soil salinity is most easily and commonly measured in terms of electrical conductivity of samples taken in the top 10 cm. However, site characterisation based on surface soil salinity measurements is clearly absurd for deep-rooted plants that will be affected by soil conditions to depths of several metres. Both salinity and soil texture might vary considerably over this depth, and there might also be considerable spatial variation across saltland sites. If considering a serious investment in this non-grazing option, an EM38 survey might be a useful starting point. Additional useful information might be obtained by conducting some drilling over the upper few metres of the soil profile. When drilling, look especially for the presence of cemented pans which can severely constrain tree rooting depths.

There are many other soil conditions that can limit the ability of trees to establish the type of deep root system that will allow them to survive in the relatively low rainfall zones where salinity most commonly occurs.

The overall conclusion is that there are many risks and challenges associated with commercial tree operations on saltland, and there are no measurements that can be made that will guarantee success over the long timeframes associated with commercial forestry.

WATERLOGGING AND SURFACE WATER MANAGEMENT

Waterlogging can be a significant impediment to tree establishment, growth and long-term survival. Removing surface water through diversion banks, surface drains or planting on beds might be necessary, although clearly this can represent a significant expense.

If subsurface drainage is planned, not only the expense, but also downstream implications must be considered, and in most jurisdictions, development approval will be needed.

THE BENEFITS

PRODUCTION

CSIRO Forestry and Forest Products has evaluated a wide range of provenances, families and clones of selected species for survival, growth and water use on saline sites. As a general rule, growth rates on saline sites decrease significantly with increasing salinity, but growth is also influenced by other soil and site conditions. Mean annual increment [stem volume] (MAI) is the usual measure of growth rate, and not only is there considerable variation between species, there is also variation between provenances of the same species and then from plant to plant.

Following this evaluation work, selection has led to lines with improved salinity tolerance, waterlogging tolerance and combined salinity and waterlogging tolerance. However, even clones from these selections can show variable stem form, crown volume and susceptibility to insect damage.

Selected clones may survive and grow better than seedling trees under saline conditions, but the gains from this improved performance must be assessed against the added costs.

Commercial clonal lines of hybrid eucalypts combine the salt tolerance and timber characteristics of *E. camaldulensis* with the growth rate, wood quality and form of *E. grandis* and *E. globulus*. While hybrid clones have not performed consistently in field trials there have been some encouraging results from selected lines. It will take several more years to confidently assess later-age growth rates and wood properties of hybrid eucalypts, particularly as soil salinity increases in the root zone or as soil sodicity develops with receding watertables.[73]

CSIRO's *Water for a Healthy Country* program has highlighted the potential of *Acacia stenophylla*,[73] which is adapted to saline, heavy clay soils in arid and semi-arid areas where supplementary groundwater is available. It tolerates drought and periodic waterlogging and flooding, and some provenances show both higher survival rates and grow taller under saline conditions than non-saline conditions.

A. stenophylla could have potential in the craftwood and specialty timber markets as well as food production from seeds. DPI Victoria has been encouraging its increased use as part of the response to salinity on riverine plains.

A. stenophylla, along with *E. camaldulensis*, is one of the few species from the Murray-Darling Basin for which any significant amount of data is available. Aside from its ability to cope with waterlogging and high levels of salinity, it has other useful characteristics for revegetation (e.g. high seed production, prolific germination, fast growth, ability to sucker and nitrogen fixing capabilities).

DPI Victoria has measured production from trees irrigated with saline water as part of its 'Trees for Profit' species trials. These repeated measurements of height and diameter growth show the performance of species considered to have commercial potential over the course of a rotation, during which the trees must cope with root zone salt accumulation.

WATER USE

Tree planting on or near to saline discharge areas has the potential to lower saline watertables, which can be important in protecting stream water quality by minimising saline runoff or seepage. These effects, where they occur, are only local unless tree planting is extensive throughout the catchment. A useful rule of thumb is that tree roots will extend from the base of a tree for distances of about two tree heights. This is, therefore, the distance over which the tree roots will take up water; however the drainage benefits may occur over longer distances.

Watertables will be reduced by a combination of reduced recharge, due to interception by tree canopies and extraction of fresh soil moisture, along with direct extraction of groundwater. But research has shown that this latter diminishes rapidly with increasing salinity; little lowering of watertables is expected once the salinity of groundwater exceeds EC 10 dS/m.[74]

The actual rate of water use from groundwater is uncertain, because it is difficult to partition water use between surface soil moisture and groundwater, although it seems reasonably certain that trees will mostly use the least saline water accessible to them in the root zone. In areas with a strong winter/summer seasonal pattern in rainfall, this will generally mean that they will use the shallow soil moisture in winter and the deeper groundwater in summer.

When trees take up water from the groundwater salts accumulate in the root zone. When watertables are lowered beneath a tree, groundwater flows towards the tree carrying the salt dissolved in that water. This movement of salt continues to occur while the trees are able to lower local watertables. Eventually the salt that has moved towards the root-zones may reach such high concentrations that the growth and transpiration of the trees are inhibited.[74] There are now a few examples where this effect has been monitored in the field; however the implications of this effect for the long-term performance of trees in the field is not known.

Most of the current evidence indicates that at groundwater salinities too high for economically productive tree growth, there are also very limited benefits in terms of lowered watertables. On the other hand, non-commercial species such as *Melaleuca halmaturorum* and *Casuarina glauca* and *C. obesa* could be usefully planted for environmental and amenity purposes.

AMENITY AND ENVIRONMENTAL

There is little question that including trees in a revegetation plan can transform salt-affected sites otherwise supporting only sparse sea barleygrass. This improved visual amenity is a strong motivator for many farmers revegetating saltland, and the opportunities for growing trees on saltland are greatly increased if environmental improvements and visual amenity are the primary goals.

The overall impact of tree planting on streams is more difficult to predict. Reducing saline flows into streams can be an important function of trees on saltland, and in most instances, keeping salt out of water courses is considered a very good outcome. On the other hand, reducing the flow of salts into streams can also be associated with an even greater reduction in the flow of water which might not be a desirable result. Landholders contemplating the planting of trees on saltland adjacent to streams might be well advised to seek advice about the possible outcomes for stream flow and salt loads from local hydrologists or catchment authorities.

HOW THE $$$s STACK UP

It is difficult to find any examples of farmer experiences showing commercial gains from planting trees on saltland. This might be partly because there are such long time delays between planting trees and commercial harvesting, but more likely because profitable forestry operations on saltland are likely to be rare.

The Australian Government is aiming for an emissions trading scheme to commence in 2010 and is committed to ensuring that incentives for abatement are maintained in the lead up to scheme's commencement. These carbon credits offer the potential for a completely different financial outcome from forestry on saltland.[75]

Carbon credits represent abatement, and can be used to counterbalance emissions that are covered by the emissions trading scheme. They can also be bought by firms, events or individuals wishing to voluntarily reduce or offset their carbon emissions, even if they are not liable parties under the trading scheme.

It is not possible to advise on the potential for tree planting on saltland within the emissions trading framework until the Australian Government announces details of the program. This is particularly the case if trees are to be harvested and processed into consumables, or if there is the possibility that the trees will die and the credits may need to be bought back.

CRC Salinity researchers undertook economic analyses for two case studies of farm forestry on saline discharge sites in Western Australia. These case studies utilised *Eucalyptus occidentalis* (flat-topped yate) and *E. camaldulensis* (river red gum) and used sensitivity analysis to identify the productivity, market conditions and/or management strategies that may be required to make these species a viable commercial option for growers or investors.

Results from the *E. occidentalis* case study indicate that timber production on this site is not viable, unless growth rates are substantially more than had been measured. Integrating the trees with pasture for sheep production may result in the investment breaking even, but the potential return from saltbush belts integrated with pasture represent a better option.

The *E. camaldulensis* case study represented a viable alternative, providing the land holder carried a level of debt close to $100/ha for 14 years until the trees are harvested. This analysis ignored any hydrological and environmental benefits which might increase the value of the trees to the landholder or the risk that changes in the site's salinity might make it unsuitable for forestry.[75]

ESTABLISHMENT AND MANAGEMENT

SITE PREPARATION

Saltland sites are often quite variable and should be thoroughly assessed for extent of soil salinity, the depth to the watertable and the salinity of the groundwater. After just a few months, tree growth is going to be driven substantially by the salinity of the deeper root-zone, so the salinity of sites should be assessed to depths of at least 50 cm, preferably deeper. The EM38 may also be a useful tool. Watertable depths can be determined by installing observation bores in representative locations, and the salinity of the groundwater can be determined by taking samples of that water with a sludge pump and measuring its electrical conductivity. At the simplest level, salinity indicator plants may give some indication of salinity levels, although generally only at the top few centimetres.

CHOOSING THE RIGHT SPECIES AND VARIETIES

Selected, predominantly native, tree and shrub species suitable for planting on soils of different salinity. Bold type indicates species that are at least moderately tolerant of waterlogging. From Trees for Saline Landscapes by Marcar and Crawford.[76]

Size	Rootzone salinity (EC_e dS/m)			
	Slight (2-4)	Moderate (4-8)	High (8-16)	Severe (>16)
Tree	***Acacia. Mearnsii***	***A. pendula***	*A. ampliceps*	***A. stenophylla***
	A. melanoxylon	***All. luehmannii***	***A. maconochieana***	***C. obesa***
	Cor. citriodora subsp. *variegata E*	***All. verticillata***	***A. salicina***	
	Cor. maculate	***C. cristata***	***C. glauca***	
	E. aggregata	***C. cunninghamiana subsp. cunninghamiana***	*E. kondininensis*	
	E. botryoides	*E. astringens subsp. astringens*	***E. occidentalis***	
	E. brockwayi	***E. camaldulensis***	***E. platypus*** subsp. ***platypus***	
	E. camphora subsp. ***humeana***	*E. campaspe*	***E. sargentii***	
	E. cinerea subsp. ***cinerea***	*E. gomphocephala*	***E. spathulata***	
	E. cladocalyx	***E. largiflorens***	***M. leucadendra***	
	E. coolabah	***E. leucoxylon subsp. leucoxylon***		
	E. cornuta	***E. melliodora***		
	E. crenulata	***E. moluccana***		
	E. globulus subsp. *bicostata*	*E. polybractea*		
	E. globulus subsp. *globulus*	***E. raveretiana***		
	E. grandis	***E. robusta***		
	E. loxophleba subsp. *lissophloia*	***E. rudis subsp. rudis***		
	E. microcarpa	*E. salicola*		
	E. ovata var. ovata	***E. tereticornis subsp. tereticornis***		
	E. saligna	*E. wandoo subsp. wandoo*		
	E. sideroxylon	***M. quinquenervia***		
	E. tricarpa	***M. styphelioides***		
	E. viminalis subsp. ***viminalis***	*P. pinaster*		
	P. brutia	*P. radiata*		
Shrub	*A. implexa*	*A. acuminata*	*A. cyclops*	***M. halmaturorum***
	A. iteaphylla	***A. redolens***	***A. retinodes***	***M. thyoides***
	A. longifolia	***A. saligna***	*E. halophila*	
	angustissima subsp. *angustissima*	*A. victoriae*	***M. cuticularis***	
	M. armillaris subsp. ***armillaris***	*E. famelica*	***M. lanceolata***	
		M. acuminata		
		M. squarrosa		
		M. bracteata		
		M. decussata		
		M. ericifoli		
		M. lateriflora		
		M. linariifolia		
		M. uncinata		

Fencing from livestock and controlling rabbits and hares are standard procedures for protecting trees during the establishment phase.

As with pasture establishment, reducing the incidence of waterlogging by removing surface and subsurface water through drains can mean the difference between establishment success and failure. Drainage might only be by shallow drains to remove surface water, but could involve deeper groundwater drains or even pumping. All these tactics impose significant costs to the project – slotted pipe (tile or plastic drains) and mole drains, or both would usually be justified only in the most potentially profitable situations and where disposal of the effluent is manageable.

Deep ripping (30–50 cm) can assist root penetration vertically and laterally, although this is rarely necessary on waterlogged sites. On dry sites, ripping on the contour increases moisture capture and availability to the plants. Ripping should be carried out several months ahead of planting to allow soil consolidation to fill air cavities, and should never be when soil is too wet or very dry.

Mounding is very important, particularly on waterlogged sites. Provided that there are orientated correctly mounds can also assist with surface water drainage; they will usually increase the amount of salt that can be flushed from the root zone of the establishing plants. On heavy, more salt-affected and waterlogged soils, mounds need to be higher and wider with a shallow trough at the top of the mound to capture rain.

WEED AND PEST CONTROL

Weed control is an essential component of tree establishment and on saline sites is generally achieved with a combination of knockdown herbicide (e.g. glyphosate and amitrol) and residual (e.g. simazine and propazine). Herbicides can be used over mounds, usually at lower rates than on non-mounded or undisturbed soil, and applied several months before planting and again at or just prior to planting, using strips 1 m wide centred on the planting line.

Weed control might be necessary a year after planting, which might be easier if plastic tree guards are used to initially protect the seedlings from rabbits, hares and kangaroos.

Trees under stress from salinity or waterlogging are generally more susceptible to damage from native insects, however this vulnerability is no more apparent in newly planted seedlings than in trees that are well established.

SOWING AND PLANTING

Seedlings are generally preferred, rather than direct seeding, for establishing trees on saline sites, particularly at high salinities and in the presence of waterlogging. However, there are many examples where direct seeding has been successful so that local experience should be checked before deciding on how to proceed.

Seedlings should be hardened off (by reducing shading, watering and nutrient application) for at least a month before planting, but should be well watered immediately before leaving the nursery and at the time of planting.

Mulching is helpful for the usual reasons of suppressing weeds and conserving moisture, but in this instance it also helps reduce the build up of salts associated with the evaporation of soil moisture from the soil surface.

GENERAL PRINCIPLES

Fertiliser is seldom required for seedling establishment, but can be beneficial for early growth to overcome later weed competition and to sustain acceptable growth rates. The application should be targeted to 'feed' the trees and not encourage increased weed growth and competition.

Planting is best when the soil is moist and warm but not waterlogged, preferably after good soaking rains have had a chance to leach salts from the surface. These conditions can be difficult to arrange in the best of circumstances, but even more on saline sites which can very quickly become waterlogged.

On cold sites (e.g. tableland areas of the eastern mainland States and in Tasmania), avoid planting in autumn, but be prepared to use plastic tree guards to protect seedlings from frost if planted in early spring.

High soil salinity and waterlogging have a similar effect to drought in restricting moisture availability to seedlings, so time the planting early enough to avoid the risk of hot spells for a few months. Waterlogging can often be minimised with drainage before planting and along with mounding will allow earlier planting, with more time for strong growth as moisture recedes in the dry season.

Gypsum (calcium sulphate) can be added to the soil to amend soil sodicity. Application rates vary depending on the degree of sodicity but range from 2.5 to 10 t/ha, and to be effective the soluble calcium must be incorporated or able to leach into the root zone.

SILVICULTURE

Tree planting at sites with less than about 600 mm annual average or at sites with low salinity can begin at high densities up to 2,500 stems/ha, a density which is generally suitable for short-rotation pulpwood production. This encourages good form and enables the selection of good quality stems for the final crop trees, but they need to be thinned early (time depends on growth rate) to concentrate growth on a smaller number of stems. Spacing between rows for sawlog production is about 4 m to allow for slashing, thinning and harvesting.

If form is unimportant, it may be more cost-effective on highly saline discharge areas with shallow watertables to plant trees at a relatively low density (e.g. 500-800 stems/ha) principally to increase site water use with limited prospect of a commercial return. This reduces planting and subsequent thinning costs, with the timber suitable for firewood.

Spacing is not important where sites are devoted entirely to biodiversity enhancement using local species, however there will be casualties if competition for good water, nutrients and light is too great.

Trees grown for high-value wood products such as sawn timber or veneer may need to be thinned several times to progressively reduce the density of the stand until only the largest, best-quality trees remain. Plantings can be thinned from around 1000 stems/ha to 600-800 stems/ha, and then to 200-300 stems/ha at a second thinning depending on climate and soil moisture. Thinnings may yield firewood, posts, poles, pulpwood or sawlogs. Thinning will probably reduce the overall water use of the stand, depending on species, stand age, density, intensity and type of thinning. Realistically, the demanding requirements associated with high value wood products are rarely likely to be satisfied at saline sites.

Pruning will generally increase the value of trees harvested for sawn timber or veneer by reducing the size of knots. On the other hand, plantations for pulpwood will not need thinning or pruning, usually being coppiced on short rotations (8–15 years).

Unused portions of trees such as under-sized stems, branches, bark and foliage should be left on site, where they will decay over time and return nutrients to the soil.

Irrigation with saline water can lead to accumulation of salts in the plant's root zone, and have other detrimental affects on soil chemistry and structure. Therefore inputs of salt via irrigation water will need to be balanced by export of salt from the root-zone. Such export may be possible in areas with deep watertables but is unlikely to occur if watertables are shallow (within 2 m of the soil surface).

Small volumes of water (0.4–1.5 ML/ha) should be applied regularly during the growing season to compensate for losses through evaporation and deep drainage. The quality of water will have different effects depending on soil texture and degree of salinity and sodicity. Irrigation with low-salinity water is best on saline or non-saline soil, but not on sodic soils where the clay minerals will disperse. Irrigation with moderately saline water (EC < 0.8 dS/m) improves structural problems in sodic soils, while highly saline water (EC >2 dS/m) will improve the structure of clay soils but will increase soil salinity unless there are opportunities for leaching.

MANAGING INSECT PESTS

A favoured approach to reducing the impact of insect damage is to choose species or seed sources of trees that are relatively resistant to insect attack. For example, *E. grandis* and juvenile *E. globulus* are known to be very susceptible to insect attack while *E. occidentalis* is resistant in eastern Australia. 'Silverton' or 'inland' forms of *E. camaldulensis* are relatively resistant to lerps but many of the northern Victorian provenances are quite susceptible. Furthermore, if local seed is being collected, avoid collecting from trees that show the signs of heavy insect attack.

Integrated pest management (IPM) uses complementary control procedures in a co-ordinated way to reduce damage by insect pests. In its most desirable form, IPM relies on the natural enemies (predators, parasitoids, pathogens) of insect pests to reduce pest numbers to acceptable levels. Chemical insecticides are only used when significant economic loss is likely to occur. Biological control can be augmented with the use of biological insecticides which are often very specific. For example, biological pesticides containing *Bacillus thuringiensis* can be used against the early stages of moth and beetle larvae.

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Glossary

Alluvial – Describes material deposited by, or in transit in flowing water.

Aquifer – A saturated geological material, that when drilled, can yield a useable quantity of groundwater. In the context of salinity, we often think of aquifers as being the material through which water moves in its path from recharge areas to discharge areas.

Baseflow – The water in a stream that results from groundwater discharge to the stream. This discharge often maintains flows during seasonal dry periods and has important ecological functions.

Capability (of saltland) – The inherent potential of saltland to be productive and profitable. This is determined by a number of factors (relating to soils, landscape, climate), but in particular relating to the decline in productive potential associated with increasing salinity and waterlogging. It can be quantified in DSE/ha for grazing land. Pasture options for optimising productivity will vary as saltland capability varies (e.g. due to salinity and waterlogging conditions).

Catchment – An area of land that drains surface water to a common outlet. A catchment is usually made up of many sub-catchments of the tributary streams to that river.

CRC Salinity – Cooperative Research Centre for Plant-based Management of Dryland Salinity. This CRC operated between July 2000 and June 2007, and was a partner in the Sustainable Grazing on Saline Lands (SGSL) Initiative.

CRC Future Farm Industries – Cooperative Research Centre for Future Farm Industries. This CRC succeeded the CRC Salinity, and is conducting current research in 'Farming Saline Landscapes'.

Discharge – Outflow of groundwater as seepage from transverse flow, or as capillary rise from shallow watertables. This often produces the symptoms of dryland salinity (i.e. bare ground, salt crusts, waterlogging and/or changes in vegetation).

DM – Dry matter, a measure of pasture productivity (e.g. kg DM/ha).

DSE – Dry sheep equivalent, a standard unit frequently used to compare the feed requirements of different classes of stock. By definition, a 50 kg wether maintaining a constant weight has a DSE rating of 1 (and an energy requirement of 8.5 to 9 MJ/day).

DWLBC – Department of Water, Land and Biodiversity Conservation.

EC, EC_e, $EC_{1:5}$, ECa – EC is an abbreviation for electrical conductivity. The individual units have been defined on page 23 – Measuring salinity of soil samples.

Electromagnetic (EM) surveys – The detection and mapping of variability in sub-surface conductivity (spatially and with depth) through the application of electromagnetic fields. The variability measured can be caused by the presence of salt, moisture, clay materials and conductive minerals. Ground-truthing (through soil sampling) is required to correlate EM survey data to attributes such as soil salinity. Survey systems vary in complexity from hand-held meters to GPS-equipped, data-logging quad-bike systems and even airborne systems for larger-scale deeper (regional) surveys.

Groundwater – Underground water contained in a saturated zone of soil or geological strata.

Groundwater Flow System (GFS) – Different types of GFS characterise the scale of a groundwater system and are determined by the relief of the landscape and topographic position in a regional context. Aside from the scale of groundwater flow paths, the term GFS also encompasses notions of a range of hydrogeological attributes which help to describe groundwater system behaviour (e.g. magnitude and delays in groundwater response to significant rainfall events or land use change). Three broad classes of GFS are recognised:

- Local systems – occur in small sub-catchments in hilly areas. Flow paths between recharge and discharge areas are less than 5 km. Groundwater flow patterns correlate well with surface topography. These systems are the most responsive to recharge reduction strategies.
- Intermediate systems – occur in larger catchments with flat plateau or alluvial valley fills. Flow paths are in the range 5-50 km.

- Regional systems – occur in large sedimentary basins / broad riverine plains and have large horizontal flow scales, greater than 50 km. These larger systems can be sluggish in nature, taking longer to show signs of salinity, or can be very responsive if geological materials are highly transmissive (e.g. limestone aquifers). Depending on geology, they can be the least responsive to management changes. If engineering solutions (e.g. drainage, groundwater pumping) are not possible, the use of saltland pasture is critical in the productive use of this kind of landscape.

Inundation – Flooding of the land surface and plants by excess surface water.

Recharge – Unused rainwater, or surface water inflows, which percolate down through the soil profile below root zones to the watertable, which causes watertables to rise.

Salinity – Salinity refers to the presence of dissolved salts in soil and water. Salinity can be natural ('primary' salinity) or caused by land management practices ('secondary' salinity). In naturally saline areas, the plants and animals have evolved to cope with these conditions. In contrast, in areas of secondary (human-induced) salinity, a build up of salt can adversely impact on water, soil, vegetation or agricultural production. Salinity can occur with or without a watertable influence.

Salinity units and measurement – The simplest measurement of salinity is to determine the electrical conductivity (EC) of a water sample. That is, how easily a solution will pass an electric current.

SARDI – South Australian Research and Development Institute (see 'Contacts and websites').

SGSL – 'Sustainable Grazing on Saline Lands' Initiative.

Sodic soil – A soil with a relatively high proportion of exchangeable sodium on the clay particles. This can cause soil structural problems. Saline conditions alleviate sodicity issues in soil, but when rain leaches out salts (freshening the soil water) this can cause clay particles to de-aggregate and disperse. The dispersed clay particles move through the soil clogging pores and reducing infiltration and drainage. On drying they can form a hard-setting layer. At an exchangeable sodium percentage (ESP) of six soils are deemed sodic, and in most cases will disperse at this and higher ESP values. Dispersion increases with increasing ESP and pH. Applying gypsum to alkaline soils (and/or lime to acid soils or soils affected by acid sulphate) may help to displace the sodium, and improve soil structure.

Soil structure – The way in which soil particles aggregate or group together. Well structured soils are those with higher clay and organic matter contents in which the particles are held together as friable aggregates, crumbs or peds. Pure sands do not have this capacity and are said to have an 'apedal' structure.

Soil texture – is determined by the relative amounts of sand, silt and clay in a soil. Texture strongly influences soil properties such as structure, water infiltration, moisture and nutrient retention, plant available water, trafficability and ease of tillage. Clays have a greater ability to absorb water than sands, therefore the conversion factor used to estimate EC_e values from $EC_{1:5}$ values will depend on soil texture.

Stolon – a prostrate stem, at or just below the surface of the ground that produces new plants from buds at its tips or nodes.

Surface water – Water in streams, creeks, rivers, lakes, dams, reservoirs and other surface water bodies.

Topography – Relief and form of a land surface.

Waterlogging – a soil is waterlogged if any part of the plant root zone is saturated with water. High waterlogging occurs when the soil is saturated to within 10 cm of the soil surface over the winter. Indicators of waterlogging include a shallow watertable, continued wetness of the soil surface, presence of weeds such as rushes (*Juncus* spp.), water buttons (*Cotula* spp.), sea barleygrass and/or puccinellia; patchy or stunted crop and pasture growth; yellowing or reddening of leaves; excessive growth of algae; "rotten egg gas" smell from soil (a sign of anaerobic conditions); presence of dull yellow mottles (minor waterlogging) or blue-grey mottles (strong waterlogging) in the soil profile.

Watertable – Is the presence of water in near surface soils at saturated levels. The watertable level is the surface in an unconfined aquifer where the water in the soil pores is held at atmospheric pressure – above the watertable, the water in soil pores is held at pressures above atmospheric. It is the height to which the water level will rise in a well drilled into an unconfined aquifer.

Notes

Notes