Book 4 Dryland Salinity: Productive Use of Saline Land and Water

Introduction

Managing dryland salinity successfully requires treatment of both the causes and the symptoms. Treatment of the symptoms of salinity in a local area requires a targeted and site specific approach. There are a range of different management options that can be combined to take account of the diverse climate, soils, hydrology and agricultural practices within a region.

Rehabilitating saline land can reduce the rate at which salinity is spreading and decrease the area of land affected. Other benefits of rehabilitating saline land include:

- increased production by replacing largely unproductive annual species such as sea barley grass *(Hordeum marinum)* with more productive perennial species;
- decreased soil erosion by maintaining ground cover;
- reduced surface soil salinity by minimising evaporation;
- improved site aesthetics and value;
- reduced saline runoff into watercourses;
- improved water quality on-site, for example, refreshing of salinised creeks and springs; and
- reduced saline discharge through use of salt and/or waterlogging tolerant trees and pasture.

Available management options vary in type and scale and should be selected to suit the social and economic needs of the community as well as the environmental conditions.

This book describes salinity management options that provide environmental benefits, while at the same time enabling the productive use of saline land and water. It uses the salinity classifications described in the second booklet in this series, *Dryland Salinity - Identifying Saline Sites,* to identify appropriate management options.

Management Issues

Dryland salinity is an important consideration in any farm plan. Addressing salinity on a whole farm basis ensures that measures adopted to treat salinity provide maximum benefits for the investment. Including salinity management in both farm and business plans ensures that on-ground works are prioritised and fit in with long-term farm goals.

A farm plan which manages salinity effectively should have regard to four factors: business considerations, vegetation, soil and water. The factors are discussed in detail below.

Business considerations

Salinity treatments must be affordable and able to be maintained in the long term. Understanding how the management of a saline area fits in with long-term whole farm management objectives is especially important for high input options such as saltbush and farm forestry, and must be fully considered before implementing major works.

Planning is also important to ensure that the salinity management measures adopted are not counterproductive to the smooth running of the farm business. For example:

- when establishing pastures or fodder shrub, consideration should be given to paddock sizes, location of watering points and the ability to manage grazing pressure in saline areas;
- establishing perennial pastures in cropping paddocks may require a considerable lead time to allow salt tolerant crops to be grown in the short-term to improve soil health and weed control before sowing to perennial pastures; and

- tree-lot design should take account of both the primary purpose of the planting, in the case of salinity control, along with other issues such as provision of shelterbelts or laneways, future access, access needs for fire control and thinning.

It is therefore critical that the farm and business plans reflect the need to maintain enterprise viability during these transition periods, especially in situations where commodity prices and/or interest rates may fluctuate. Long-term business profitability is necessary for the successful incorporation of effective salinity management measures into long term sustainable farming practices.

Vegetation

Vegetation plays an important role in the prevention and treatment of saline surface outbreaks. The type of vegetation and its placement can be used to restore or maintain the water balance in a catchment.

Perennial pastures can be placed anywhere in the catchment. Ideally, a mixture of warm and cool season plants will ensure that water is used for active growth all year round. Trees and shrubs should be placed where groundwater needs to be intercepted as the root systems of pasture plants are generally too shallow to access this water.

Trees and shrubs use the most water in a limited area, whereas pastures use less water but over a greater area.

Annual crops use little annual rainfall and only during the growing season. When they are small their root systems are not deep enough to access all of the available soil moisture and when they mature and ‘hay off' they use negligible amounts of water. Conversely perennial pastures with a mixture of cool and warm season plants are able to intercept rainfall throughout the year. Native trees also use water year round, but their greatest use occurs during the warm season.

Crops, pastures, fodder shrubs and trees can all be grown in saline areas with appropriate management. Some plants are able to withstand high levels of salinity while others are very sensitive even to low levels of salinity. Species choice will vary according to the location of planting. Plants that are placed close to the saline area will need to be more salt tolerant than others. Table 1 shows the salinity level at which production starts to decline for some common crop and pasture plants.

Table 1: Salinity Levels at which production begins to decline .

Crop Tolerance	**Level of soil salinity (EC_e) at which plants begin to decline**	**Soil Salinity Class**	**Pasture Tolerance**
Sensitive Crops turnip, strawberry, beans, carrot	0 - 1 dS/m	N/A	**Sensitive Pastures**
Moderately Sensitive Crops potato, grapes, corn, cowpea, linseed	1 - 2 dS/m	N/A	**Moderately Sensitive Pastures** most clovers, medics,
Moderately Tolerant Crops grain sorghum, rice	2 - 4 dS/m	1	**Moderately Tolerant Pastures** lucerne, 'salt tolerant' lucerne, kikuyu, phalaris
Tolerant Crops oats, sorghum, wheat, canola, safflower, soybean,	4 - 8 dS/m	2	**Tolerant Pastures** couch, oats, fescue, phalaris, perennial ryegrass, balansa

sunflower			clover, burmuda grass, Pioneer rhodes grass buffel grass
Very Tolerant Crops barley, cotton	8 - 16 dS/m	3	**Very Tolerant Pastures** tall wheat grass, dundas wheat grass, Puccinellia, palastine strawberry clover,
Generally too saline for crops	> 16 dS/m	4	**Very Tolerant Pastures** salt bush, blue bush, distichlis

Cropping of saline land often results in soil degradation and expansion of the saline area and delivers few benefits. The return on investment can be poor in the short-term and unsustainable in the long-term. Crops are usually sown early to avoid problems with waterlogging. Special equipment is needed to minimise tillage and damage to soil structure.

Cropping saline land can cause significant problems, for example:

- bare soil increases evaporation resulting in increased soil salinity;
- volunteer grasses, for example, couch compete with crops and are hard to control;
- low crop emergence;
- waterlogging leading to plant diseases;
- early haying off and pinched grain due to moisture stress on plants;
- uneven ripening;
- reduced accessibility and traffic movement; and
- early sowing increases the risk of frosting.

Salinity is sometimes caused, and other times accompanied, by permanent or periodic waterlogging. Waterlogging limits the amount of air available to plants and, although some pastures have adapted to these conditions, crops seldom grow well in saline and/or waterlogged areas. Some trees and fodder shrubs can be established in waterlogged areas, but only if they are planted into raised beds or mounds.

The long-term success of vegetation in saline areas depends on the correct species choice and ongoing management to promote growth and water use.

Soil

Agricultural soils have been degraded over time. Poor soil health affects soil structure and plant growth and this exacerbates the impacts of salinity.

Any agricultural practice that improves groundcover, soil structure, organic matter, soil chemical health, nutrient balance or soil pH (high and low) will have a positive effect on salinity. This principle should be applied to the whole farm including salt affected areas.

When considering treatment of saline areas, remember that salinity may not be the only limiting factor. Acidity, alkalinity, sodicity and other soil toxicity may be present. For this reason it is advisable to test soil and water for a range of factors. Soil testing gives information on the nutrient and chemical profile of the soil. A physical inspection provides information on soil structure and groundcover. Table 2 defines soil salinity classes according to the level of salinity.

Table 2: EC e Values of soil salinity classes.

Class	Salinity Class	ECe	Comments
Non-saline	0	<2	Possible waterlogging
Slightly saline	1	2-4	Some salt tolerant species (eg. sea barley grass) but no bare patches
Moderately saline	2	4-8	Small bare patches
Very saline	3	8-16	Large bare areas
Highly saline	4	>16	

Water

Managing dryland salinity involves controlling the way water moves through the landscape. The more rainfall that can be used where it falls, the fewer salts will be dissolved from soil and rock and redistributed to saline areas.

There are two types of water moving around a catchment, surface water and groundwater. Surface water is generally fresh but may become saline where it interacts with groundwater, for example, where saline springs discharge into creeks or when flowing over a saline site. The type of soil and rock water flows through has an impact on toxicities other than salinity that may be present. A water test is an ideal way to assess the quality of water and determine what it may be used for.

The source of saline groundwater coming to the surface and causing salinity is a major consideration. Engineering works to control water movement, such as drainage of saline water, are generally very expensive and require technical and legal expertise.

Saline water can be used for various purposes, depending on the level of salinity and other contaminants. This book uses the water salinity classes in Table 3 to identify options for water use. The standard units of measurement for water salinity are deciSiemens per metre (dS/m) and milligrams per Litre (mg/L).

Table 3: AWRC saline water quality classes.

Water Quality Class	level in dS/m	levels in mg/L (equal to ppm)
Fresh	less than 0.8 dS/m	less than 500mg/L
Marginal	0.8 – 1.6 dS/m	500 - 1000mg/L
Brackish	1.6 – 4.8 dS/m	1000 - 3000mg/L
Saline	greater than 4.8 dS/m	greater than 3000mg/L

Source: AWRC1976 in Taylor 1993

Establishing salt tolerant pastures

Sowing salt tolerant pastures is often a successful way to treat saline and waterlogged sites. They are easy to establish, provide early economic returns and protect the soil from further degradation. Salt

tolerant pastures add organic matter to the soil and improve soil structure. They can also be sown in between rows of saltbush or other edible shrubs.

The preparation for pasture establishment needs to begin a year before the growing season, especially with regard to weed control. Good grazing management is important for the long-term persistence and productivity of pastures. The main steps in establishing salt tolerant pastures are outlined below.

Selecting salt tolerant pasture species

Table 4 below recommends salt tolerant species for different classes of saline soil. The table can be used to develop a mix of salt tolerant pasture species for southern, central and northern NSW. It is best to select a combination of grasses and clovers based on rainfall (amount and the season), degree and season of waterlogging, soil pH and soil fertility.

It is important to consider these factors when selecting a pasture mix. For example:

- a low to moderate salinity site in a moderate rainfall (approximately 550-600mm) area in southern NSW (eg Young) may use Phalaris, Tall Wheat Grass, Fescue, Sub and Balansa clovers;
- a moderate to high salinity site in a moderate rainfall (approximately 550-600mm) area in northern NSW (eg Narrabri) may use Rhodes Grass, Tall Wheat Grass, and Pucinnella and Lotus clovers if the site is waterlogged; and
- although seeding rates are high in saline areas because salinity reduces emergence, the total seed rate should not exceed 12 kg/ha. Rates listed below are a guide and may be adjusted to suit the 12 kg limit.

Always seek advice from your local agronomist before making saline pasture decisions.

Table 4: Pasture Species for Saline Areas.

Species	**Sowing Rate (kg/ha)**	**Salt Tolerance**	**Water-logging Tolerance**	**Summer Drought Tolerance**	**Acidity tolerance (low pH)**	**Salt land Class Suitability**	**Rainfall Range * (mm)**
Phalaris	2	Moderate	Moderate	High (dormant)	Sensitive	Class 1 Class2	550 Sth to 750 Nth
Tall Wheat Grass	4-6 6-10*	Moderate	Moderate	Moderate	Moderatel y Tolerant	Class 2 Class 3	400 Sth to 500 Nth
Perennial Ryegrass	0.5	Low	Moderate	Low	Moderatel y Tolerant	Class 1 Class2	700 Sth to 800 Nth
Fescue	4	Low to Moderate	High	Low	Moderatel y Tolerant	Class 1 Class2	750 Sth
Puccinella	2-4	Moderate	High	Low	Sensitive	Class 2 Class 3	400 Sth to 500 Nth
Makar-ikari Grass	2-4	Low to Moderate	High	High	Moderate	Class 1	450 Nth

Lucerne	0.5-3	Low	Low	Low to Moderate	Sensitive	Class 1	375 Sth to 450 Nth
Rhodes Grass	1-4	Moderate	Low – Moderate	Moderate	Tolerant (but Al sensitive)	Class 1 Class 2	500 Nth
Subclover	2-3	Low to Moderate	Low to moderate	High (annual)	Moderatel y Tolerant	Class 1	500 Sth
Balansa Clover	0.5 -1	Low	High	High (annual)	Moderatel y Tolerant (but Al sensitive)	Class 1 Class2	550 Sth
Straw-berry Clover	1-2	Moderate	Moderate	Low	Sensitive	Class 1 Class2 Class 3	600 Sth to 650 Nth
White Clover	0.5-3	Low	Moderate	Low	Low to Moderate	Class 1	700 Sth to 775 Nth
Lotus	1-2	Moderate	High	Low	Tolerant	Class 1	900 Nth
Couch's Marine & Sea water	N/A Est. by runners	High	High	Low	Tolerant	Class 3	Saline / waterlog sites
Disticylus	N/A Est. by runners	High	High	Low	Unknown	Class 3	Saline / waterlog sites

* Areas with summer waterlogging may take species with higher rainfall requirements.

NB: The above is not a complete list of cultivars per species.

Steps to establish salt tolerant pasture

- **Step 1 - Planning and long term weed control**

  Record the period of waterlogging. This will give an indication of the best time to sow the area, that is, while the area is still trafficable.

  Soil test the area to determine what ameliorants, for example, phosphorous, gypsum or lime, need to be added to ensure optimal growth.

  As with all new pastures, areas to be sown should have a weed control plan that is commenced at least one year prior to sowing. Most species on saline sites are annuals and will need to have their seed set reduced in the year prior to sowing. This can be done with either knock down or selective herbicides depending on the species condition of the site. For example, if the site is actively eroding, avoid knockdown herbicides.

  Other weeds common to saline areas, such as Juncus species, may have specific management requirements, such as the use of fire or wick wipers, so it is important to talk to an agronomist when planning your weed control program.

- **Step 2 - Pre-sowing works**

  You may need to divert water away from the area to prevent erosion. This will depend on the site slope and soil type. Seek advice before undertaking any earthworks on these sites as incorrect work can exacerbate the problems. Fence the area to allow control of future grazing.

- **Step 3 - Pre sowing weed control**

  Winter/spring: Graze the area heavily in early spring to reduce the bulk of material. This will also ensure even growth of annual grass species which is important for effective herbicide control.

  Spring: Spray fallow in late spring/early summer when trafficable and at the emergence of seed heads of annuals such as Sea Barley Grass. A knock down herbicide can be used to do this. It is also possible to include an insecticide to control earth mites.

  Summer: On sites with large amounts of Couch an extra summer spray may be needed.

  Autumn: Use a knockdown spray in autumn after the break. If the site becomes very wet in early autumn, it may be necessary to sow as soon as it rains; however, this will result in more competition for the newly sown pasture.

- **Step 4 - Sowing**

  It is important to sow in autumn, before it becomes too wet. However, in the central and northern areas of the region, it is possible to sow in spring and get a good result providing usual summer rainfall occurs.

  Optimum sowing techniques will vary from site to site. For example:

- Flatter sites - use a conventional combine without harrows. Drop the seed on top to avoid burial.
- Highly saline - working with a scarifier just prior to sowing may assist, then proceed as above.
- Sloping sites - direct drill seeding will minimise the erosion hazard. Sow the seed as shallow as possible to avoid water lying in the slots during winter.
- Extremely wet sites - if the area is not accessible most of the year, hand broadcasting seed may be the only way to establish pasture species.

  It is very important to obtain a current soil test of the area to help make sensible fertiliser and ameliorant (lime or gypsum) decisions. Also be aware that, on saline sites, soil pH can be unpredictable. In many cases they have a high pH and can occasionally be very acidic.

  On acid soils, an application of lime at 2.5 t/ha will aid pasture establishment. Lime should be applied as early as possible prior to sowing, particularly if it is not incorporated. Applications of gypsum of 1.5 - 2.5 t/ha can aid establishment on saline/sodic soils by improving soil structure and reducing soil crusting. The gypsum will also help rectify sulphur deficiencies in the soil.

  At sowing use a fertiliser containing phosphorous, nitrogen and sulphur. “Starter” type fertilisers, such a MAP, DAP, Granulok can be used at rates of 125 – 250 kg/ha. The adding of nutrients should be done in conjunction with a soil test.

  Seed should be treated with an insecticide to prevent ant theft. Legume seed should be lime coated and can also be treated with molybdenum.

  Please note if dealing with Class 3 land, do not work or spray fallow the area. These areas are extremely fragile. Instead apply fertiliser, lime or gypsum to area and then broadcast either by hand or super spreader seed directly to the area.

- **Step 5 - Post emergence**

  To ensure the successful establishment of the new pasture, delay grazing for at least twelve months. Use the paddock as a feed gap reserve, that is, graze for a short period in late summer/early autumn each year.

- **Step 6 - Ongoing management**

  The following principles should be employed to ensure the survival and productivity of your new pasture into the future:

- allow perennials to set seed in the first year and then every 2-3 years after;
- do not allow pastures to become rank, only growing leaves use water; and
- do not graze if the site is waterlogged, too dry or bare areas are present.

  Fertilise regularly. An application of Molybdenum fortified superphosphate every 4-5 years aids legume persistence, particularly if the site is acid.

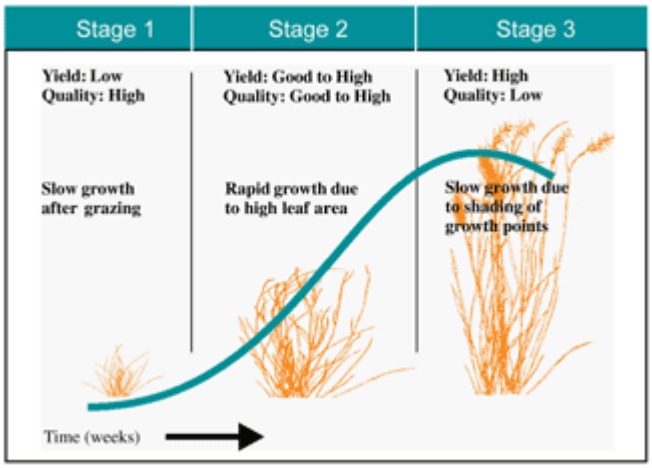
Grazing management for saline sites

Grazing management is one of the most powerful tools in the overall management of the landscape. A well-grazed pasture is more productive, long-lived and of higher feed quality than poorly grazed pasture. Good grazing management increases stock productivity, improves long-term pasture productivity and protects the soil surface. Timing stock movement between paddocks and assessing the pasture stage are important skills for grazing management. Leaving stock in a paddock for too long, at **high or low** density, will cause overgrazing.

The most productive pastures are generally 5-15cm tall, 1000-3000kg Dry matter per hectare (DM/ha) and are growing vigorously (represented by Stage 2 growth in the figure below). Feed quality and quantity are both moderate and growth is maintained after grazing through a well-developed root system. The well-developed root system and vigorous growth allows plants to access and use rainfall.

Figure 1: Pasture growth after grazing

Stage 1 **Stage 2** **Stage 3**



Source: Prograze manual : NSW Agriculture

Establishing trees and shrubs in saline areas

Discharge areas are unsuitable for growing many types of trees, especially when the site is severely affected. A number of factors interact with salinity to make the local environment more toxic. Waterlogging is the main factor impeding tree establishment and growth, however, soil texture, climate, frost, soil structure and nutrients may also have an effect. Some varieties of trees are more salt tolerant or can adapt better to saline sites. Planting trees on lower slopes above or away from the seep / scald can help to improve growth and increase water use.

Selection of salt tolerant tree and shrub species

The table below may be used as a reference when selecting a mix of salt tolerant trees and shrubs suitable for planting on saline sites in southern and central NSW. Planting a combination of species across a site reduces the risk of failure and enhances the biodiversity and shelter benefits achievable from the planting.

Table 5: Tree and shrub species for saline areas .

Botanical name	**Common name**	**Class 1 2-4 dS/m Slightly saline**	**Class 2 4-8 dS/m Moderately saline**	**Class 3 8 + dS/m Very saline**	**Class 4 16 + dS/m Highly saline**	**Uses**
Acacia mearnsii	green wattle	*	*			A, C, F
Acacia melanoxylon	blackwood	*	*			A, E, F
Acacia salicina	willow wattle	*	*	*		A, G, ?
Acacia saligna #	orange wattle	*	*	*		G, F
Acacia stenophylla	river cooba		*	*	*	A, C, D, G, ?
Atriplex spp #	saltbush	*	*	*	*	G
Casuarina cunninghamiana	river she oak	*	*	*		A, C, F
Casuarina glauca*	swamp she oak	*	*	*	*	A, C, H
Casuarina obesa	WA swamp oak	*	*	*	*	A
Eucalpytus astringens #	brown mallet	*	*			A, C, F
Eucalyptus camaldulensis*	river red gum	*	*	*		A, C, E, F
Eucalyptus camphora #	swamp gum	*	*			A, C
Eucalyptus	sugar gum	*	*			A, B, E, G

cladocalyx #						
Eucalyptus kondinensis	stocking gum	*	*	*	*	
Eucalyptus largiflorens #	black box	*	*	*		A, C, F
Eucalyptus leucoxylon #	yellow gum	*	*	*		A, C, E, ?
Eucalyptus melliodora	yellow box	*	*			A, C, E, F
Eucalyptus microtheca #	coolibah	*	*	*		A, C, F
Eucalyptus occidentalis* #	flat top yate		*	*	*	A, C, F
Eucalyptus ovata	swamp gum	*				A, C, E, F
Eucalyptus sargentii #	sargents mallet	*	*	*	*	
Eucalyptus sideroxylon	iron bark	*	*			A, C, E, F
Eucalyptus spathulata	swamp mallet	*	*	*		
Eucalyptus tereticornis #	forest blue gum	*	*	*		A, C, E, F
Eucalyptus viminalis	manna gum	*				F, E
Maireana brevifolia	blue bush	*	*	*	*	G
Melaleuca halmaturorum	swamp paper bark	*	*	*	*	A
Tamarix aphylla	Athol tree	*	*	*	*	A

Note: the 'Uses' column refers to the following:

A Firewood
B Preserved posts
C Durable posts
D Pulpwood (>600mm annual rainfall)
E Sawlogs (>500mm annual rainfall)
F Honey, pollen or attractive to bees
G Fodder

* Denotes provenance variation within species.

# Denotes frost susceptibility

Steps for establishing salt tolerant trees and shrubs

A general guide for the establishment of trees and shrubs on saline land is provided below. Many texts are available offering more detail on tree establishment for farms. Preparation for the establishment of trees and shrubs should begin at least twelve months before planting.

- **Step 1 - Planning**

- Use visual assessment or the techniques described in *Dryland Salinity - Identification and Assessment of Saline Sites* to define the salinity affected area.
- Where waterlogging or erosion are a problem, divert run-off away from the area to prevent erosion. See your local land management adviser for advice.
- Record the period of waterlogging. This will give an indication of the best time to carry out operations. Planting usually occurs in early spring to allow trees to establish before the heat of summer. Autumn planting is also carried out in some districts.

- **Step 2 – Long term weed control**

- Graze heavily to knock down weeds and pasture plants.
- Late spring/ early summer: Spray fallow the whole tree lot area while the site is trafficable. Using glyphosphate at the full head emergence of the earliest flowering plants to prevent seeding of annual weeds. Weeds will compete strongly with the trees in the following year if left uncontrolled.
- Summer: Where the site is dominated by a mat of Couch grass apply a high rate of glyphosphate (3.0 L/ha). This application needs to be repeated twice, four to six weeks apart as one application will only retard, not kill, the Couch. (*Hertel,K. pers comm* .)
- Late winter: Spray the mounds in autumn with a mixture of glyphosphate and include a surfactant and Simezine to provide residual weed control. Aim to spray one month before the trees are planted to give the weeds time to break down. Glyphosphate rates should be high enough to ensure good weed control, including pasture species. In saline sites, Trizine chemicals (for example, Simezine, Atrizine) can have long term residual effects, so low to moderate rates can be used.

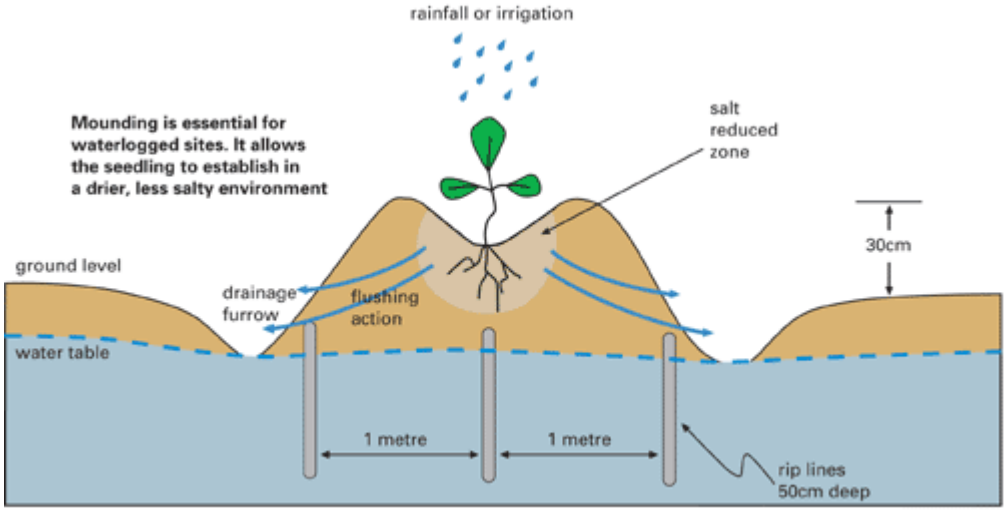
- **Step 3 – Pre planting works (ripping and mounding)**

  Deep rip and mound in late summer/early autumn. Ripping should be at least 60cm deep. Ripping is important as it allows the tree roots to penetrate deep into the soil. Trees with constricted roots often die after one to two years. Rip lines are commonly four metres apart to allow for growth of the trees, while maintaining a high density for water use. Wider spacing is used where pasture is planned between the rows of trees. For saltbush and trees that are not required for windbreaks, tree rows can be spaced to allow sowing of salt tolerant pastures in between.

  Mounds are needed in saline areas to allow salts to leach away from the tree roots. At least six months is needed between mounding and planting to allow the mounds to settle, to force out air pockets and reduce clods. Air pockets around the roots of young trees will kill them.

  Mounding is extremely important on waterlogged sites as it creates an aerated zone where plant roots can access oxygen and carbon dioxide for growth. Figure 2 shows a mound designed for such areas. Ideally, mounding should be carried out one year before planting to allow salts to be leached out of the centre niche.

Figure 2: Mound design for waterlogged areas



Adapted from Michele Dignand, 1993

Plate 1: Mounding to allow salts to leach away from the tree roots.

- **Step 4 – Fencing**

  Erect a fence around the area. Tree lots need to be separated from areas to be grazed because stock will damage and kill the trees. Leave enough room between the fence and the tree rows to protect trees from stock and protect the fence from falling tree limbs in the future. A distance of four metres or more will also allow vehicular access to the tree lot. At least one gate should be included in the fence.

- **Step 5 - Planting**

  Water trees well on the day of planting to reduce stress. Plant in early spring at the desired density. Trees can be planted by hand using a planter such as a ‘Hamilton' (removes a plug of soil) or ‘Potaputki' (forces soil outward forming a hole). Mechanical planters can also be used. Whichever planting method is used, it is vital to ensure soil contact with the trees' potting medium. Air pockets around the roots of the trees will kill them. Good contact can be attained by firmly stomping around the planted trees, ensuring that the top of the potting medium is covered by soil to reduce evaporation.

  Farm forestry trees are planted every three metres along the rip line in anticipation of three-quarters of the trees eventually being removed by thinning. In windbreaks, biodiversity and aesthetic planting's, shrubs may be placed every four metres on outer rows and trees every five to six metres on inner rows. This reduces competition and the need to thin, as well as providing some protection from falling limbs for fencing.

- **Step 6 – post planting options for enhancing growth**

- Mulching around trees with straw reduces evaporation, soil reflectance and soil temperatures around young trees. This is especially effective in increasing survival when planting into bare or scalded ground.
- Trees establish better when they are guarded, although guards add considerable cost to establishing trees. Trees can be left unguarded if no protection from weeds, animal perdition, sun or wind is needed. On saline areas, the shade provided by guards increases survival by reducing evaporation and reflection of heat from the bare soil.
- For forestry trees, low phosphorous fertiliser is thought to aid in early growth, whereas high phosphorous fertiliser can damage native species. Apply forty grams of a “starter” fertiliser such as DAP to the soil, close to the tree but not touching the stem.
- Trees can be watered in, increasing contact between the potting medium and the soil and reducing air pockets that dry out tree roots.

Plate 2: Rehabilitated saline area.

Management of trees on saline sites

Management of the planting site is important for young trees and shrubs. Do not allow stock access to the trees until the stock cannot reach the growing tip and the trees are large enough to withstand browsing and rubbing by stock, at around two to five years after establishment.

Where no pasture has been established between the tree or shrub rows, weeds and pasture species will invade the bare site. If this is the case, expect the site to look untidy for the first couple of years while the trees and shrubs establish. After a couple of years the trees and shrubs will be large enough to shade out weeds and pasture plants. Thinning forestry species at canopy closure will encourage pasture plants to persist.

Considerations for saltbush and fodder shrubs

Saltbush is often considered for saline sites because it tolerates high salinity levels, however, there are several other factors that need to be considered. Saltbush does not tolerate extended periods of waterlogging or being planted in frost prone areas. Saltbush is not tolerant of acid soils as aluminium (Al) becomes available, which is highly toxic to saltbush.

If saltbush is being considered, soil test for pH and aluminium in both the topsoil (zero to ten centimetres) and subsoil (ten to twenty centimetres). If aluminium comprises more than two percent of the cation exchange capacity (CEC) in the topsoil, apply lime to correct it. If subsoil aluminium is a problem, saltbush should not be planted.

Once fodder shrubs are established, grazing must be managed to promote growth and maximum yield to increase water use. Lightly graze the shrubs when they have reached about sixty centimetres in height, as the roots will have established a good hold on the soil. The paddock can be used as a feed gap reserve and should be grazed on an eighty day cycle. Let stock graze the leaves of the bushes and remove them when they begin to nibble the stems. The length of time this takes is dependent on the stocking density and other feed available in the paddock.

It is important to supply good quality water when grazing saltbush or blue bush, as stock will avoid an excessive daily salt intake. The more salt in the fodder the less the stock can tolerate in their water.

Management of saline soils

Increasing land and water salinity is a symptom of human activity on a landscape rich in salts. Past agricultural practices have contributed to the loss of topsoil, organic matter, soil structure, nutrients and groundcover, and a decline in chemical health including acidification, in some areas.

These factors have reduced the soil's ability to hold rainfall as soil water, and plants' ability to use the water. This encourages leakage of water to the groundwater system that can result in waterlogging and salinity.

Soils on saline discharge areas generally deteriorate with time if left untreated. Bare patches increase the toxic levels of salt at the soil surface, which inhibits plant germination and reduces the range of species that can be grown. The earlier saline discharge is identified, the easier and cheaper it is to treat.

Any agricultural practice that improves groundcover, soil structure, organic matter, soil chemical health, nutrient balance or soil pH will have a positive effect on salinity. This principle should be applied to the whole farm, including any salt affected areas. Both chemical and physical improvements need to be made to saline areas to achieve rehabilitation. When both approaches are used in conjunction they have a much greater effect than when used in isolation.

Soil chemical health

Soil testing provides information on the nutrient and chemical health of the soil and is an important first step in the assessment of saline areas. Although an area may be saline, soil salinity may not be the limiting factor. Acidity, alkalinity, sodicity and other imbalances may be present.

Treating the soil chemically may include adding fertiliser to boost plant growth as well as treating the soil chemistry itself. However, the application rates of many soil conditioners is worked out using mathematical formulae that do not account for the soil's physical properties such as texture, for example, sandy soils are less able to retain conditioners than clay soils. Because the addition of unnecessary or excessive amounts of nutrients can create further imbalances and is expensive, it should be informed by the results of a soil test properly interpreted by a land management adviser.

Most saline soils have an excess of sodium that can be corrected by adding lime or gypsum. The calcium in these products replaces sodium in the soil, which is then leached away by rainfall. Applying lime and/or gypsum to saline areas reduces the soil toxicity and provides a buffer against the toxic effects of soil salts. The gypsum will also help rectify sulphur deficiencies in the soil.

Soil physical health

Common physical problems in saline soil include compaction, waterlogging, poor structure and high levels of salts. Options for the physical treatment of saline soils includes establishing and managing groundcover, managing grazing pressure and crop rotations.

Plant growth can improve saline and sodic soils by making soil-pores for air and water to enter, providing food for soil fauna and increasing carbon dioxide levels, which in turn increases the solubility of lime. The groundcover created by plants reduces the likelihood and severity of erosion and can assist in the rehabilitation of existing erosion.

Organic matter on the soil surface, living or dead, reduces the heat and reflectance of the soil. This reduces evaporation and therefore concentration of salts in the soil surface and creates habitat for soil fauna to incorporate the organic matter deeper into the soil.

It takes several years to build organic matter in the soil under the commonly employed farming practices. Formation of soil organic matter is also dependent on rainfall. Soil in lower rainfall area experience less opportunity to build up organic matter (Murphy, Lawrie & Stanger, 2000).

Organic matter can be imported into a saline area in the form of mulch, for example, the litter created when stock are fed bales on scalded areas or old bales are spread out over a scalded site. Grazing management can also be used to retain and build organic matter in the soil.

Treatment of saline-sodic soils

Sodic soils can be treated chemically by the addition of organic matter and by changing cropping practices. Murphy, Lawrie and Stanger (2000) discuss the treatment of saline sodic soils in more detail in. A brief overview is provided below.

When saline-sodic soils are treated for salinity and salts are removed from the soil, the soil can become dispersive. To avoid this, the soil EC needs to be maintained by the addition of gypsum at 1.5 - 2.5 tonnes per hectare. Gypsum also improves soil structure and reduces soil crusting. In some cases, small amounts of gypsum can be added on a regular basis, for example, 0.5 - 1 tonnes per hectare per year.

Lime can also be used to maintain soil EC but is less effective because its solubility is lower than that of gypsum, although it does last longer in the soil. Soils with a high clay content require higher levels of lime or gypsum.

The mixing of subsoil with topsoil is a problem in sodic soils because highly dispersive soils are often found within ten to twenty centimetres of the surface. The dispersive soil should not be mixed with the surface soil. The best cropping practices for sodic soils are those that reduce tillage and maintain surface cover, that is retain soil structure. However, caution is required when adopting reduced or minimum tillage operations because specialised equipment is required so making the changeover can be expensive. For example, one pass sowing needs equipment with a minimum Tyenna breakout pressure of 90kgf (200 lbw) up to 225 kgf (500 lbw).

Water quality

Water levels and salinity measurements are essential parts of any salinity study. Because the lead time for changes in water quality resulting from salinity management activities can be very long. These measurements are best taken over several years with careful interpretation of results so that trends can be identified and cause-effect relationships between the interventions and water quality can be established.

Plate 3: Surface water sampling.

Water salinity thresholds

Water salinity can be measured with a hand held salinity meter on site, or by a water sample test available through NSW Agriculture. Methods for water salinity measurement are discussed in greater detail in *Book 2: Dryland Salinity - Identifying Saline Sites* . Table 6 below is a guide to interpreting salinity measurements.

Table 6: Water salinity levels for various uses

Source/Use	**EC (dS/m)**
Distilled Water	0.00
River Murray (SA, 1993)	0.79
Desirable potable limit for humans	0.83
Grape, potato, sweet corn yields reduced by 10%	1.7
Lucerne yield reduced by 10%	2.2
Absolute potable limit for humans	2.5
Limit for mixing herbicide sprays	4.69
Limit for poultry	5.8
Limit for pigs	6.6
Limit for dairy cattle	10.00
Limit for horses	11.60
Limit for beef cattle	16.6
Limit for adult sheep on dry feed	23.00
Sea water	50.00
The Dead Sea	555.00

Source: Dowelling in Taylor 1993

Water salinity levels for healthy growth of livestock

Factors affecting tolerance of stock to saline waters include:

- overall salinity levels;
- type of salts;
- age and health of the animal;
- climate and weather;
- freshness and aeration of the water;
- distance stock must travel to water;
- salt levels in available feed; and
- other water contaminants.

Table 7 lists the maximum levels of salinity in stock water for healthy growth of livestock. Some stock will seek water that is higher in salinity than in Table 7, while others will decline to drink water of lower salinity. This has to do with the factors listed above, whether stock are introduced to saline water gradually or not as well as the types of salt present in the water. Some salts are more toxic than others

and the only way to find out what type of salts are in the water is to have the water tested by NSW Agriculture or other NATA registered laboratories.

Stock can be introduced to saline waters gradually through shandying fresh and saline water. Although this generally increases stock tolerance to saline water, their growth, breeding and maintenance will still be affected.

Table 7: Maximum levels of water salinity for healthy growth of livestock

Use	EC (dS/m)
Pigs	3.2
Poultry	3.2
Cattle (dairy)	4.8
Horses	6.4
Cattle (beef)	6.4
Sheep (dry feed)	9.6

Source SCS (1989) in Taylor 1993

Common toxicities for stock water

The common toxicities that can occur in waters draining from saline sites or in saline groundwater are detailed below, adapted from DNR Qld (1997). Table 9 provides an overview of the maximum concentrations of different substances tolerated by livestock in stock water. If you suspect stock are being affected by their drinking water, have a water sample tested at a NATA approved lab and contact your stock agronomist or veterinarian for advice.

Calcium - ANZECC (1992) recommends that, if calcium is dominant, the total calcium should not exceed 1,000 mg/L. If the water also has high concentrations of magnesium and sodium, the acceptable level of calcium is lower than 1000mg/L.

Sodium Bicarbonate - is a common salt in water. Water dominated by sodium bicarbonate can cause sheep to bloat, particularly if they are under stress or not accustomed to the water (Chippendale, 1972 in Gill 1986a, in DNR Qld).

Magnesium - High levels of magnesium can cause scouring in stock. Magnesium level greater than 600mg/L (>600mg/L) are generally unsuitable for all stock (Flynn 1984 in ANZECC 1992). Where magnesium levels are less than 600mg/L (<600mg/L) the water suitability is a function of salinity. Table 8 shows the relationship based on sheep and cattle husbandry:

Table 8: Suitability of stock water containing <600mg/L of magnesium

EC (dS/m)	TDS (mg/L)	Recommendations
< 7.8	<5 000	Suitable for sheep & cattle of all ages
7.8 – 15.6	5 000 – 10 000	Suitable for dries mature sheep & cattle. Unsuitable for lambs, calves & weaners. Caution needed with lactating stock if unaccustomed.
>15.6	>10 000	Suitable for dries mature sheep. Caution needed with cattle if unaccustomed.

Sulphate - can occur on saline sites and wash off into waters accessed by stock. High sulphate levels can cause scouring and general loss of condition (ANZECC 1992). Sulphates in a saline area can produce a slick black layer in the soil and also give a slight sulphur smell.

Table 9: Maximum concentrations of ions or salts in stock water

Ion or Salt	Stock type	Maximum concentration (mg/L) ANZECC 1992 & Gill 1986b
Calcium	all stock	1000
Sulphate	sheep cattle horses other stock	60 40 30 30
Sodium bicarbonate	all stock	1000
Magnesium *	all stock	600

* see table 8 for further breakdown

Other uses for saline land and water

Salt affected land can provide business opportunities, as well as providing a substrate for growth of salt tolerant pastures, trees and shrubs as described above. Most opportunities provide industries with "niche" markets, so a thorough understanding of markets, costs and salinity impacts will need to be investigated prior to embarking upon these ventures.

Redemption of saline sites can offer flow on benefits, such as allowing extraction of salts for commercial use from a saline water table that also reduces the impact of salinity on that site. A recent National Dryland Salinity Program (NDSP) project – *Options for the Productive Use of Salinity (OPUS)* - conducted extensive research and case study evaluation into viable industry alternatives being employed across Australia and documenting potential salinity options. The NDSP website provides access to the OPUS database and the saline industry categories listed below for land managers interested in exploring these alternatives.

Agriculture

- salt tolerant crops
- salt tolerant pasture (grasses)
- salt tolerant pasture (legumes)
- forage/fodder
- alternative meat production

Forestry and Horticulture

- forestry products
- non-timber forestry products
- horticulture

Fauna and Algae

- inland saline aquaculture
- algae
- seaweed

Minerals

- salt products
- other mineral products
- desalination

Energy

- thermal energy
- biomass energy
- heat convection

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