Managing Vulnerable Soils under Irrigation in Tasmania

Department of Primary Industries, Parks, Water and Environment

Abstract:

This document is presented as part of the Water for Profit program and provides information in the form of guidelines or principles that will assist famers in the identification and management of a range of vulnerable soils now being used under irrigation

Contact:

Land Management Enquiries: 171 Westbury Road PROSPECT TAS 7250, Phone: 03 6777 2227, Email: LandManagement.Enquiries@dpipwe.tas.gov.au

Cover photo: Erosion in a newly sown Ferrosol paddock near Deloraine, Tasmania (photo taken by R. Parkinson, DPIPWE)

Contents

Managing Vulnerable Soils under Irrigation in Tasmania

Introduction

Tasmania's agricultural landscape has developed over many years with many families having remained on the same property for generations. This has led to a deep knowledge and understanding of the land's susceptibilities and its capacity to support various agricultural enterprises. In recent years however, there has been a considerable investment in irrigation development resulting in a huge increase in the area of land under centre pivot irrigators which has brought with it new opportunities for production and different challenges in managing a range of vulnerable soils. Given that many of Tasmanian soils are fragile and prone to degradation if not appropriately managed it is considered a timely opportunity to bring together the existing information on soil management with information on vulnerable soils and suggestions for irrigation management.

This document is presented as part of the Water for Profit program and provides information in the form of guidelines or principles that will assist famers in the identification and management of a range of vulnerable soils now being used under irrigation. It follows a review of information on the management of vulnerable soils currently available in the literature and the World Wide Web. While the review acknowledged the wealth and diversity of information currently available on managing soil hazards in general it also highlighted that this information is often scattered, not specific to Tasmania or Tasmanian soils, and often not straightforward for farmers to trace. In Tasmania there exist a number of documents that provide useful information on managing Tasmanian soils (eg. Chilvers 1996, Hamlet 2002, and Cotching 2009) and it was hoped that this set of guidelines would further expand on information in those publications. While the review made recommendations on options for creating a set of guidelines that might be of direct benefit to farmers through the use of Tasmanian examples of successful management of vulnerable soils under an irrigated farming system time and resources have meant a different approach be adopted and hence the preparation of information in this paper.

The Guidelines presented in this paper are therefore simply a summation of existing information. The Guidelines by nature cannot be prescriptive but simply present a set of principles to guide good decision-making together with some information and ideas that can be adapted for use on various soil types. Each property owner's ability to implement the guidelines will depend upon their own circumstances, soil types, aims and farming operations. However, application of the guidelines will assist in achieving more reliable productivity and less environmental damage.

While these guidelines provide information on the *management* of various soil vulnerabilities in the irrigated agricultural areas of Tasmania, the Water for Profit program mapping has produced vulnerability mapping that extends Statewide to assist land management agencies, organisations and individuals view the soil vulnerabilities in those areas. These Statewide maps can be accessed here:

https://maps.thelist.tas.gov.au/listmap/app/list/map?bookmarkId=383124

Whilst some of the more fundamental management principles outlined in this paper may still apply to land outside the irrigated agricultural areas of Tasmania, guidance and specific management advise for soil vulnerabilities in those areas lie outside of the scope of this document.

Using the Guidelines and the soil vulnerability surfaces in combination allows farmers to make more informed decisions about appropriate land management options for soils on their property. Much of the information provided in the following pages is not new. Indeed, most is contained within the existing publications by Chilvers (1996) and Hamlet (2002) available through the DPIPWE web site. What is new is the introduction of irrigation and the added pressures that this imposes on the land.

This document therefore draws together information from various existing sources and provides additional guidance on the use of irrigation in areas identified by the soil vulnerability maps as being at risk of degradation. The application of traditional soil management practices still applies to those soils under irrigation but appropriate irrigation management is also critical to minimizing soil resource degradation.

Irrigation and Land Capability

In applying the guidelines consideration should be given to the capability of the land to support intensified agriculture. Land capability classification (LCC) has been undertaken for most agricultural areas of Tasmania. The LCC provides a ranking of the ability of land to sustain a range of agricultural land uses (Grose 1999). The system takes into account the physical nature of the land and climate conditions and assesses the various limitations they impose on the ability of the land to sustain agricultural production. Based upon these constraints the system set out broad intensities of land use for the various capability classes. The system also assumed a good level of land management and that, except on the red Ferrosols, the soils were unirrigated. The widespread development of irrigation throughout much of the north, central and southern midlands of Tasmania in recent years adds an additional level of farm management complexity. In many instances, however, it will not change the capability of the land to sustain production. Only where production is limited by low rainfall will irrigation permit more intensive use of the land without the risk of increased degradation. Many of Tasmania's soils are constrained by factors other than moisture; stoniness, fragile soil structure, drainage constraints, erosion risk and salinity to name but a few. Some of these constraints can be overcome through high levels of management but these usually come with increased costs. Availability of irrigation water should not be used as justification for managing land beyond its capability. By its very nature farming and agricultural production, cropping enterprises in particular, often lead to:

- declining organic matter levels as a result of oxidation of carbon following cultivation
- declining pH through use of acidifying fertilisers and removal of agricultural products
- soil compaction or soil structure decline through vehicle trafficking or regular cultivation.

Work by Cotching (*et al.* 2002a, b and c) and Sparrow (*et al.* 1999) has demonstrated the potential adverse impacts of long term or regular cropping in some Tasmanian soils and further work by DPIPWE, investigating changes in soil condition over time, suggest that many (cropping) soils are showing small adverse changes in one or more indicators of soil condition over time (though it is unclear as to whether these changes are a real trend or simply reflecting changing seasonal conditions or different stages of the cropping cycle). These impacts can be minimized, or even avoided altogether, by employing a good level of land management, by using land within its capability (including avoidance of over cropping and allowing adequate rest periods for the soil to recover) and by ensuring efficient and appropriate irrigation management.

Thus, in applying irrigation to the land careful attention needs to be paid to the nature of the soils being irrigated; what are their limitations? How frequently will they be cropped? Do I, as the farmer, have the knowledge and resources to be able to apply an appropriate level of management needed for the proposed intensity of use? It is important to remember that *using* land within its capability is only one step in the process of sustainable production as it also needs to be *managed* within its capability.

Principles for Best Practice Irrigation Management

Developments in irrigation technology in recent years, together with investments in water storage and distribution, have given many Tasmanian farmers the opportunity to diversify their land use and grow crops in areas traditionally considered too dry or rainfall too unreliable for crop production. Even in areas where crops have been grown in the past reliable access to irrigation water increases opportunities for production and reduces risk of crop failure during times of low rainfall. However, with increased opportunity there comes increased responsibility. Most Tasmanian agricultural properties have a diversity of soil types many of which are fragile or susceptible to various forms of degradation. The Agricultural Land Capability Classification undertaken across the State in the late 1990's attempted to provide some guidance to property owners in the capability of their land to support various intensities of agriculture and tried to identify some of the constraints that might limit the range of appropriate activities. Soil, topographic and climate constraints may all have an impact on the ability of the land to support agricultural activity and some soils may become more vulnerable to some constraints, soil drainage, soil sodicity, erosion for example, under irrigation. Indeed, rather than improving the capability of the land irrigation has the potential, in some circumstances, to reduce its capability.

Thus successful irrigation agriculture is not simply a matter of buying an irrigator and turning on the tap. If not properly designed for the soil type on which it is operating, carefully maintained and managed farm irrigation systems can be costly to run and damaging to the soil resource, far outweighing the benefits of any increased production that may result.

Managing vulnerable soils under irrigation often starts with managing the irrigation system itself as a well-designed and implemented irrigation system can help to minimize running costs, increase water use efficiency and decrease damage to the soil. Optimal irrigation system design requires controlling water flow velocities to match the capacity of the soil being irrigated. The best design will be influenced by pump and pipe capacities, elevations water might need to be lifted, water volumes needed, area to be irrigated, irrigation rates and frequency, nozzle sizes and a variety of other factors. Designing an efficient irrigation system requires knowledge of the soil hydraulic properties (eg infiltration capacity, water holding capacity) and climate conditions (evapotranspiration rates and rainfall patterns) and crop physiology (crop water needs and how they change with crop growth). The topography of the land being irrigated may also impact on the rate at which water is delivered to the soil with sprinklers concentrating application in concave areas (hollows and foot slopes) and dispersing it on convex areas (ridges). Fortunately, most irrigation equipment suppliers are able to provide all the advice you need regarding power supplies, pump sizes, flow rates, nozzle design and irrigation rates and will generally be able to design a suitable irrigation set up for your property. This doesn't mean that the irrigation designer makes all the decisions, however. Property owners will still need to decide the type of irrigation system they want, whether it is fixed or variable rate, how mobile it needs to be etc. To some extent these decisions may be governed by financial constraints and by the farmer's capacity to manage and maintain the equipment. Variable rate irrigators, for example, may need some computing skills to be able to set the variable rates according to the soils types to be irrigated and to adapt those rates as the season progresses and the crop develops.

So, you have undertaken a cost benefit analysis and determined that it is worthwhile installing an irrigation system. You have gathered the relevant climatic, soil, crop and topographic information. Your irrigation designer has looked at water supply and quality, energy sources, and daily irrigation needs. He has designed and evaluated a variety of irrigation systems from the point of performance, cost and on-farm capacity to manage and you have selected and installed an appropriate system. Now all you need to do is turn on the tap! Wrong! Now the real work begins.

Now that the irrigation system has been installed you need to start considering when to commence irrigation, how much to apply and at what rate (hopefully you already have some of this information).

Irrigation planning and scheduling is dependent upon the soil moisture state, preceding and predicted future rainfall amounts, humidity levels, crop evapotranspiration rates, rooting depth, soil infiltration rate and soil water holding capacity. Frequent monitoring of the soil moisture status is important to ensure that the right amount of irrigation is applied at the right time to minimize plant moisture stress. Monitoring can be via a variety of moisture measurement instruments but digging a hole and feeling the soil is always a good start. You can even try calibrating your assessment of the soil moisture status against instrument readings. Many irrigation paddocks are likely to contain different soils with different irrigation requirements or sensitivities to irrigation – irrigating to maximize production from one soil type may lead to degradation in other parts of the paddock. So should you invest in a variable rate irrigator (VRI) or fixed rate? How well do you know the soils in your paddock and their hydraulic properties? How much time are you willing to invest in programming and maintaining a VRI system? A method for calculating frequency and amount of irrigation is discussed later in this paper (see page 8).

Suggested Guiding Principles

It is recommended that the following principles, adapted from a case study of South Australian farmers (www.naturalresources.sa.gov.au), be followed for sustainable irrigation management. They have been developed by farmers for farmers:

- **Know the soils on your property – textures, rooting depths, capacity of soil to store water and barriers to soil water movement.**
  A knowledge of the soil types that you are irrigating will provide a better understanding of their capacity to store water, how the water will move through the soil and barriers to water movement. Knowing where water concentrates, in hollows or above impermeable layers, enables you to identify areas of impeded drainage and where irrigation rates should be reduced. Are the soils sodic? Is there a risk of salinity? What is the quality of the irrigation water I am using and how will this impact on my sodic soils? For guidelines on the management of vulnerable soils under irrigation see later in this paper (see page 10);

- **Rate irrigation management as a high priority.**
  It takes time and effort to get irrigation right. If you are unable to put in the time and effort needed then you are likely to incur higher direct costs through inefficient irrigation practices and overwatering as well as indirect costs through resource degradation and reduced productivity;

- **Design and maintain irrigation systems correctly.**
  A correctly designed and maintained irrigation system will reduce running and maintenance costs and reduce potential for damage to vulnerable soils;

- **Monitor – before, during and after irrigation.**
  Regular monitoring of the paddocks under irrigation will provide early warning of any issues that might be developing. Monitoring soil moisture contents will enable more efficient irrigation scheduling; monitor for areas under or over irrigated may assist in minimizing crop losses, monitor for signs of degradation will enable remedial action to be undertaken before the issue becomes too great (and costly). Look for signs or erosion, poor drainage and salinity;

- **Use a range of tools for irrigation scheduling**
  There are a range of tools available for monitoring soil moisture to assist with irrigation scheduling. The benefit of these is dependent on the value of your farming system. Soil moisture probes are frequently in use around vineyards, for example. The cheapest method

is simply visual observation. Dig a hole, observe the distribution of crop roots, feel the soil – both texture and moisture content;

- **Retain control of irrigation scheduling**
  Flicking a switch and walking away doesn't work. Retain control of your irrigation scheduling so that you can vary it according to conditions to issues that you observe in the paddock;
- **Maintain good records of rainfall evapotranspiration and irrigation amounts.**
  Knowing rainfall amounts and your soil enables better estimation of irrigation amounts thereby increasing irrigation efficiency and reducing costs.
- **Avoid overwatering**: creates poor drainage, saturation, reduced production; leads to erosion.

A Rough Guide to Irrigation Scheduling

As suggested earlier, management of irrigation is a critical component of ensuring sustainable production and this is particularly the case where the soils themselves have inherent vulnerabilities. Soils under irrigation are susceptible to a wide range of degradation issues if irrigation is not managed efficiently. Many of these issues are the same as might occur under natural conditions but under irrigation they can have a far greater impact on productivity.

Irrigation management is about applying the right amount of water at the right time. To achieve this it is necessary to have an understanding of some basic soil properties. These are discussed below together with a method for calculating irrigation amounts and frequency which will also require knowledge of recent climate conditions and evaporation rates. Some information is provided in this document to facilitate this process.

Soil Properties relevant to irrigation management

Dry soils typically contain about 50% airspace by volume. When this airspace is filled with water the soil is deemed to be at ***saturation point***. Soils that are saturated for long periods are stressful for plants as there is insufficient air in the soil for plant roots to utilize. Saturated soils are also prone to erosion as any further additions of water are unable to soak into the ground and therefore run off across the surface. Surface runoff can also occur on unsaturated soils when the rate of water application, either by rainfall or irrigation, exceeds the rate at which water can enter the soil, known as the ***infiltration rate***.

If a saturated soil is left to drain under gravity it eventually reaches a point where the ability of the soil to hold on to the water is equal to the force of gravity trying to remove it. This is known as ***field capacity***. As plant roots remove water from the soil the remaining water becomes harder to remove. Eventually the strength that the soil's holds on to the water exceeds the ability of the roots to remove it. This is known as the ***permanent wilting point***.

The amount of water contained in the soil between field capacity and wilting point is the ***plant available water*** or ***PAW***. PAW is dependent upon a variety of soil and plant properties. Not all PAW is equally available to plants and, as permanent wilting point is approached, soil water is held with increasing force and crops may become stressed before wilting point is reached. Thus irrigation needs to occur once the ***readily available water (raw)*** has been utilized. Estimates of RAW for different soil textures are presented in Table 1.

Table 1. RAW for a range of soil textures

Soil Texture	Readily Available Water (mm/m of soil depth)
Sand	30
Loamy sand	50
Sandy Loam	70
Loam	90
Clay	50
Clay loam (Ferrosol)	80
Clay (well structured)	60
Heavy clay	30

Source: Wise Watering. Irrigation Management Course notes, DPIPWE website.

Clearly the amount of pore space available in the soil influences the capacity of the soil to retain water. The size and continuity of these spaces is also significant. Large spaces, for example, retain water less strongly and are more likely to drain under gravity. Conversely, very fine pores may retain water too tightly for plant roots to extract.

Soil texture, the combination of clay, silt and sand sized particles, also affects moisture retention, as does the arrangement of these primary particles into *soil aggregates* that create ***soil structure***. Light sandy soils tend to have lots of pore space but hold on to water fairly weakly and much drains away before field capacity is reached. Well-structured clay soils have plenty of pore space where moisture can be held at strengths still accessible to plants. Poorly structured clay soils have little pore space and may retain water very strongly. Such soils may contain significant amounts of moisture at wilting point but it is held too tightly for plants to access.

Table 2. Determining soil texture

Texture	Feel	Ball	Ribbon length (cm)
Sand	Single grains stick to fingers and easily visible	Won't form	<0.5
Loamy sand	Very sandy or gritty, slight staining, visible sand grains	Barely holds together	0.5
Sandy loam	Sand grains can be easily felt	Makes a ball that just holds together	1.5-2.5
Loam	Spongy and smooth	Ball holds together easily	2.5
Silt Loam	Silky and smooth; may feel slightly soapy	Ball holds together easily	2.5
Sandy clay loam	Sand grains can be felt and seen; easy to work; rods form with difficulty	Ball holds together strongly	2-4
Clay loam	Plastic and smooth; easy to work up; slightly rough sheared surface	Ball holds together easily	4-5
Light Clay	easy to work; easily forms rods when worked; slight resistance to shearing; shiny, smooth smeared surface	Ball holds together easily	5-7.5
Medium clay	Moderately firm to work; easily forms rods when worked; moderate resistance to shearing; shiny, smooth smeared surface	Ball holds together strongly	>7.5
Heavy clay	Plastic and smooth; very hard to work up; will easily form thin rods when worked.	Ball holds together strongly	>7.5

Source: Adapted from Wise Watering. Irrigation Management Course notes, DPIPWE website.

Finally, the amount of water that plants can extract from soil is also dependent on the depth of soil that roots can penetrate. Deeper rooting crops have access to a greater volume of soil, and therefore potentially more PAW, than shallow rooting crops. Table 3 provides a guide for rooting depths of common crops in Tasmania.

Calculating Irrigation Volume to Apply

The amount of water needed to replenish soil water to field capacity can be calculated using the RAW values in Table 1 and the estimated rooting depth of the crop being irrigated (which will vary over the season as the crop develops).

To estimate the volume of irrigation to apply you will need to know the following:

- Your soil texture. Table 2 can be used as a guide to estimate field texture;
- The thickness of any soil layers of different texture within the rooting depth of your crop;
- An estimate of the rooting depth of your crop. Table 3 can used as a guide for Tasmanian crops when fully developed, or dig a small hole adjacent to the crop and observe the actual rooting depth.

Table 3. Root zone depths for Tasmanian Crops (fully developed)

Crop	Root Depth (m)	Crop	Root Depth (m)
Potatoes	0.6	Onions	0.3
Poppies	0.5	Broccoli	0.5
Peas	0.5	Lucerne	1.2
Green beans	0.5	Pasture	0.3
Pyrethrum	0.8	Stone Fruit	1.0
Buckwheat	0.4	Vines	0.7
Carrots	0.5		

Source: Wise Watering. Irrigation Management Course notes, DPIPWE website.

Example 1:

In this example we will use a duplex soil that has 20cm of loam over 60cm of clay loam. The crop being grown is potatoes. The calculation is:

Layer 1 thickness (m) x RAW (mm) + Layer 2 thickness (m) (or to rooting depth) x RAW (mm) = irrigation equivalent to add.

Thus: 0.2 x 90 + 0.4 x 80 = 50mm

(Note that the full thickness of the clay loam layer is not used because the rooting depth only goes 40cm into that layer)

Example 2

For the second example we will use a deep (<50cm) loamy sand growing poppies. In this example there is only one soil layer thus layer thickness is the same as rooting depth:

Layer 1 thickness = 0.5m, RAW = 70. 0.5 x 70 = 35mm

If there are more than two soil layers then the RAW for each layer thickness will need to be calculated.

Irrigation Frequency

OK, so you have an estimate of the amount of irrigation water needed but just how often should this be applied?

In order to calculate an estimate of irrigation frequency one more piece of information is needed – the rate of evaporation and water use by the crop or ***Evapotranspiration rate (ET)***. The evapotranspiration rate will vary depending upon season, weather conditions and stage of growth of crop. Table 4 provides daily average evapotranspiration per month from a well-developed crop for a variety of locations around Tasmania.

Table 4. Average daily evapotranspiration 2010-1015 for various Tasmanian locations

	Hobart	**Ouse**	**Oatlands**	**Campbell Town**	**Burnie**	**Scottsdale**
Jan	5.8	6.3	6.0	6.5	5.9	6.1
Feb	5.0	5.5	5.3	5.7	5.1	5.1
Mar	3.8	4.1	4.0	4.3	3.9	4.0
Apr	2.8	2.9	2.7	3.1	2.8	2.8
May	2.0	2.1	1.9	2.3	2.1	2.0
Jun	1.7	1.7	1.6	1.9	1.8	1.7
Jul	1.8	1.8	1.6	2.0	1.8	1.7
Aug	2.2	2.2	1.9	2.2	2.1	2.0
Sep	2.9	2.9	2.7	3.1	2.9	2.9
Oct	4.0	4.1	3.9	4.2	4.0	3.9
Nov	4.7	5.0	4.8	5.2	4.9	4.8
Dec	5.5	6.0	5.7	6.1	5.6	5.7

Source: Bureau of Meteorology data

Calculating the irrigation frequency is simply a matter of dividing the irrigation amount calculated earlier by the average daily evapotranspiration rate. Thus, in example 1 above, the irrigation amount was 50mm and, in January, ET=5.8mm/day for the Hobart area. Irrigation frequency is therefore:

50/5.8 = 8.6 days.

Similarly for example 2 above, Raw = 35mm; ET =6.1mm/day in January around Campbell Town, thus irrigation frequency should be:

35/6.1 = 5.7 days.

The above calculations are indicative of the process only. Actual irrigation amounts will depend upon specific crop rooting depths, soil textures and soil layer thickness. Furthermore, daily ET values can vary significantly and more reliable calculations can be made using more recent daily values available through the Bureau of Meteorology website. As well, modifications may need to be applied for any rainfall amounts that occur.

Designing an Irrigation System

The information provided above provides general information on how to calculate irrigation needs and frequency. Naturally this information is nonspecific and a range of other information needs to be taken into account when planning an irrigation system. What was the soil moisture content before irrigation commenced, for example; are we starting from a full or empty system or somewhere in between? Factors like the ***infiltration rate*** (how quickly water is able to enter the soil) and ***soil***

hydraulic conductivity (how quickly water moves through the soil) will all impact on the rate at which irrigation water is applied which, in turn, is dependent upon things like irrigator nozzle size and speed of traveler. Then there are other variables over which we have no control, such as the diversity of the soil texture across the paddock being irrigated.

Soil texture, structure, vegetation cover, existing soil water content and even soil temperature can all play a part in controlling soil infiltration rates and hydraulic conductivity. Typically, sandy soils have the highest infiltration and conductivity rates while clays have the slowest. Surface infiltration rates often decrease as the soil becomes saturated and this may affect the proposed irrigation rate. It is important for irrigation rates not to exceed soil infiltration rates otherwise excess surface water, unable to enter the ground, may run-off causing erosion and removing valuable organic matter and soil nutrients. Infiltration rates may also depend upon slope steepness and curvature (Table 5).

Table 5. Approximate Water infiltration rates for various soils textures and slope

	Slope		
	0-3%	**3-9%**	**9%+**
	Infiltration Rate (mm/hr)		
Sand	>25	>18	>12
Loamy sand	18-25	12.5-25	10-18
Sandy loams	12.5-25	10-18	7.5-12.5
Loams and Silt Loams	7.5-18	5-12.5	4-7.5
Sandy clay loams and silty clay loams	5-10	4-6.5	2.5-4
Clay and sandy clays	2.5-5	2.5-4	<2.5

Source: http://www.soil.ncsu.edu/certification/manual/slides/chapter5a/img14.html

Diversity of soils across a single irrigation paddock can be particularly problematic. The development of programmable variable rate irrigators has to some extent made managing a diverse paddock easier but considerable effort is still required to delineate the different irrigation zones, program and maintain the irrigator.

Suppliers of irrigation systems are generally able to provide appropriate advice and assistance with system design and should be the first point of contact when planning an irrigation development.

Recommendations for the Management of Vulnerable Soils under Irrigation in Tasmania

The remaining part of this document provides general information and advice for the management of Tasmanian soils with specific vulnerabilities. The information is offered on the basis that irrigation management is undertaken at a high level.

Best Management Practice Guidelines for Soils Vulnerable to Erosion by Wind under Irrigation

Best management of wind erosion is essentially the same whether or not the soil is irrigated. Wind erosion is typically a more common hazard in arid and semi-arid parts of Australia and can result in large dust clouds that pick up nutrient and carbon rich topsoils and deposit them often hundreds of kilometers away.

In Tasmania wind erosion is less of a problem as soil moisture helps bind soil particles together and areas susceptible to erosion by wind are often smaller than on the mainland.

Soil erosion by wind often occurs where bare sandy soils occur. However, it also occurs where finer grained soils have been heavily cultivated and the soil structure degraded to the point that individual soil particles, often less than 0.1mm in size, are dominant.

Process of Wind Erosion

Wind erosion is the detachment, transportation and redepositing of soil particles by wind. Most common result is loss of topsoil and nutrients. Irrigation is unlikely to increase the risk of irrigation by wind as the increase in soil moisture will assist in binding soil particles together.

Movement of soil particles occurs in three ways depending on the size of the soil particle and the wind strength.

Creep: Soil creep occurs when soil particles are moved only short distances and typically roll or tumble across the ground surface. This process is generally limited to larger soil particles 0.5-2mm in size.

Saltation: This process impacts on medium sized soil particles 0.05—0.5mm in diameter. These particles are lifted from the ground surface by the wind but are too heavy to remain suspended and fall back to the ground often dislodging other soil particles in the process.

Suspension: Tiny particles of soil less than 0.1mm can be lifted into the air by wind or dislodged by larger soil particles and caught up in the wind. It is the suspension of these fine particles that lead to the formation of dust clouds in which the wind energy is sufficient to keep the soil particles in suspension. Often such fine soil particles come together to create a soil structure too heavy to be eroded by wind but this structure can be degraded by overgrazing or over cultivation and removal of the ground cover leaving the soil vulnerable to wind damage.

Factors influencing soil erosion by wind

While wind is obviously the driving force behind wind erosion there are several factors that make soils more or less vulnerable to this degradation process.

The significance of soil particle size has been discussed above. Typically, the finer the soil particles the more susceptible they are to erosion by wind. Maintaining a rough soil surface assists in reducing wind speed at the ground surface, thereby reducing the energy of the wind to cause erosion. Similarly, maintaining a groundcover protects the soil from erosion by reducing the area of bare soil exposed to the wind. Not only can ground cover protect soil particles from mobilization but it also slows wind speed at the ground surface reducing the energy available to entrain soil particles. A general rule of thumb is to retain about 50% groundcover by crop or pasture residues to minimize erosion risk by wind. Minimising soil disturbance by stock or machinery can also reduce the risk of potential soil loss by wind erosion.

Management Principles for Preventing Soil Erosion by Wind in Tasmania

- Know your soil and whether it is susceptible to erosion by wind – or use the DPIPWE vulnerable soil maps on TheLIST to identify areas vulnerable to erosion by wind (see Figure 1 or https://maps.thelist.tas.gov.au/listmap/app/list/map?bookmarkId=383124 for interactive map on LISTmap);
- Be aware of weather conditions and avoid cultivating if strong winds are likely to occur;
- Practice minimum tillage operations such as direct drilling, to avoid disturbing the soil surface or damaging any weak soil structure that may be present. Avoid use of moldboard ploughs;
- Minimise periods of cultivated fallow and ensure 30-50% ground cover after harvest to prevent erosion;
- If cultivation is essential then use techniques that minimize soil aggregate degradation and don't leave a smooth soil surface (soil surface roughness helps reduce wind speed through increased friction with the ground surface). Avoid use of powered implements that tend to pulverize the soil;
- When irrigating young crops on sandy soils use frequent small volume irrigations to keep the surface soil moist until adequate crop cover has developed. This will also minimize the loss of excess irrigation water through deep drainage in these rapidly draining soils, thereby saving costs and reducing offsite or groundwater impacts;
- Avoid over grazing or grazing of cover crops until a good ground cover is established;
- If time permits irrigating a bare soil can help reduce the severity of erosion if strong winds are forecast;
- In open, flat areas, shelter belts will help reduce wind speed and therefore erosion risk;
- Following a fire plant fast growing cover crops to reduce erosion risk.

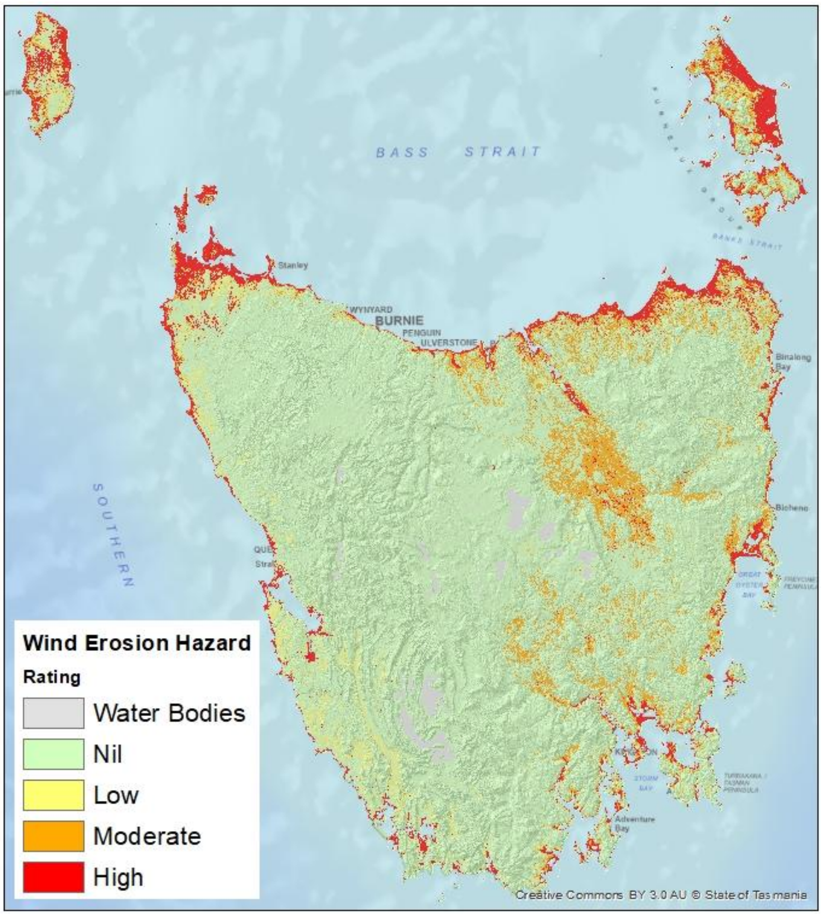

Figure 1. Wind erosion hazard map of Tasmania.

Best Management Practice Guidelines for Soils Vulnerable to Erosion by Water under Irrigation

There is much information available in the literature and online regarding managing soils to minimize erosion by water. Soil erosion by water occurs when surface water run-off occurs and the energy in the water is high enough to detach soil particles. Run-off can be a result of application rates, either through irrigation or rainfall, being greater than the infiltration capacity of the soil or as a result of saturation of surface soil layers. Depending on the degree of run-off concentration erosion may occur as sheet wash or through the development of rills and gullies. Occasionally erosion by water can result from subsurface through flow of water along preferential flow paths. This subsurface erosion can lead to tunneling, tunnel collapse and gullying. Soil erosion by water may result in both on-site and off-site impacts as not only does erosion lead to loss of topsoil and soil nutrients on-site but sediment run-off may also block or contaminate drains and waterways and often contains farm chemicals that can add to off-site pollution impacts. Controlling and minimizing soil erosion by water is an important factor in reducing costs associated with fertilizer and chemical losses, maintaining productivity through prevention of soil fertility decline and topsoil loss and minimizing environmental harm due to off-site impacts of sedimentation and chemical contamination.

Process of Water Erosion

The factors giving rise to erosion by water are generally the same whether the source of water is rainfall or irrigation. The mechanics of erosion by water requires sufficient energy from the water to be able to detach small particles of soil from the ground. This energy can be generated by water droplet size or volume of overland (or sub-surface) flow. There needs to be sufficient excess of water to generate runoff with sufficient energy to transport detached particle. This might normally occur where irrigation rates exceed soil infiltration capacity and the energy generated is dependent upon the volume of run-off, the gradient of the soil surface and the nature of any ground cover that may reduce run-off rates or increase the amount of energy required to detach soil particles.

Splash Erosion

Erosion by rain splash or irrigation droplet occurs where the energy of the water droplet is great enough to detach soil particles. Typically, this form of erosion only moves soil particles a short distance although by detaching particles soils can become more susceptible to other forms of erosion by water. Erosion by rain splash (or irrigation droplet) normally only occurs during high intensity rainfall events.

Rill and Gully Erosion

Where surface run-off occurs the energy of the water may lead to removal and transport of soil material in rills (small channels) or gullies (larger channels). As water volumes increase, or slope steepness increases, there is a corresponding increase in the energy of the overland flow to cause erosion. If concentration of overland flow does not occur but water application rates still exceed capacity of soil to absorb it, then sheetwash may occur. While sheetwash is typically an easier form of erosion to manage, as difficult to repair rills and gullies are not formed, it can still remove valuable topsoil material, organic matter and nutrients across a wide area.

Tunnel Erosion

Tunnel erosion may occur where sub-surface water flow occurs along preferential flow paths – old root channels for example – and where soil particles may be particularly easily detached as in sodosols (see later in this report). Once again there needs to be sufficient energy in the moving water to detach small particles of soil. As the water moves through the soil it carries detached particles of soil with it and detaches more soil as it travels. If the soils are sodic this allows water particles to more easily enter the microscopic gaps between soil particles, forcing them apart and mobilising them downslope. Over time this steady mobilisation and removal of soil can create subsurface soil tunnels that may grow and/or collapse into form gullies and become an increasing hazard to machinery and livestock alike.

Factors Influencing Soil Erosion by Water

Factors that influence the susceptibility of the soil to erosion by water generally relate to either the hydraulic properties of the soil or the energy of the water. Soil hydraulic properties, that is the rate at which water might enter and pass through the soil, are influenced by soil particle size, soil structure and soil chemistry (including organic matter content). Energy of the water can be influenced by water droplet size, degree of water concentration and topographic steepness. Other influencing factors may include the degree of bare soil or vegetation cover and the surface roughness of the soil surface.

Therefore, erosion may occur following high intensity rainfall (irrigation) events when application exceeds ability of the soil to accept water; erosion is likely to be worse on steeper slopes where run-off may become concentrated, on bare or relatively smooth soil surfaces. While sandy soils are generally highly permeable soil particles are often only weakly held together so once saturation occurs and run-off commences erosion losses may be greater than heavier soils. If the soils are sodic at the surface then detachment of soil particles can lead to surface crusting which reduces the infiltration capacity of the soil and creates a smooth soil surface for greater run-off.

Management Principles for Preventing Soil Erosion by Water in Tasmania

As discussed above, the soil erosion by water is a complex process that may be influenced by a wide range of factors. Under irrigation scenarios this brings a corresponding range of opportunities for managing erosion and some general principles are outlined below. In summary, soil erosion by water can be controlled through correct irrigation management; protection of the soil surface from erosion and controlling run-off before it develops sufficient energy to cause erosion.

- Know your soil and whether it is susceptible to erosion by water – or use the DPIPWE vulnerable soil maps on TheLIST to identify areas vulnerable to erosion by water (see Figure 2 or https://maps.thelist.tas.gov.au/listmap/app/list/map?bookmarkId=383132 for interactive map on LISTmap);
- Understand the hydraulic properties of your soil – how quickly can it accept water? How rapidly can it remove water and how much water can it store before saturation occurs?
- Understand your irrigation system and how application rates relate to the soil hydraulic properties;
- Avoid high energy run-off systems by avoiding steeper slopes or by employing soil cultivation techniques that increase surface roughness and/or reduce water concentration;
- In high risk areas use soil erosion control techniques that increase soil infiltration and reduce surface run-off. These might include cut-off drains, diversion and contour banks or mulched rip-lines at 25-80m spacing depending on the nature of the soil and the topographic gradient;
- Minimize periods when bare soils are exposed, particularly at times when heavy rainfall may be expected;
- Be aware of pre and post irrigation event weather conditions and how these might affect the ability of your soil to manage further water inputs.

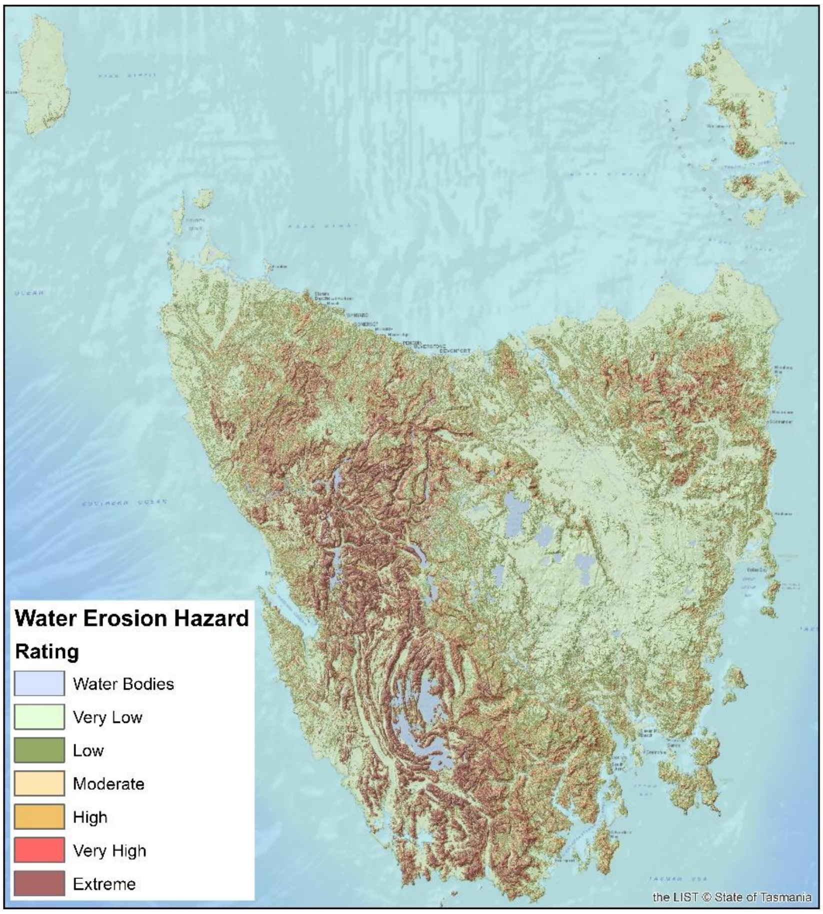

Figure 2. Water erosion (Hillslope erosivity) hazard map of Tasmania.

Best Management Practice Guidelines for Soils Vulnerable to Waterlogging under Irrigation

This section is about identifying the need for, and the causes of, waterlogging (or impeded soil drainage), particularly in an irrigation scenario. It will touch briefly upon the different types of drainage system as well as upon some of the factors to be considered in implementing a drainage system at the farm level (as opposed to a broader area). It is not intended to provide detailed information on designing soil drainage systems as they are typically site specific, nor does it address the physics of ground and soil water movement.

Waterlogging occurs when excess water saturates the soil, filling pore spaces and reducing the oxygen content of the soil. While the prime cause of waterlogging is obviously an excess of water this excess can be generated by a variety of causes. Simply put waterlogging is a result of water application rates greater than water removal rates. Water application may be via rainfall, overland or subsurface flow or irrigation. As soils become wet or saturated the amount of oxygen retained in the soil, and essential for plant root respiration, is reduced. While different plants and crops have different tolerances to waterlogging the impact is often reduced yields or death of the plant. Reducing waterlogging can therefore increase productivity and the general health of the crop.

A well-designed and implemented irrigation system should minimize the use of excess irrigation water, aim to optimize available water use thereby reducing irrigation costs and necessity for soil drainage management. In reality, given the variable nature of soil, topography and climate, achieving such a goal is next to impossible. The need for a drainage management plan should be considered when planning an irrigation scheme. To achieve the best results a good knowledge of the soil types to be irrigated and how they will respond to irrigation, together with an understanding of the characteristics of the proposed irrigation design, are essential.

Factors influencing the degree and severity of waterlogging.

Every soil has a natural or inherent drainage status governed by a combination of soil properties. Soil texture, the relative proportions of sand silt and clay sized particles is perhaps the primary soil property affecting drainage status. In turn, soil texture may influence soil structure which itself influence the amount of pore space within the soil and thus the amount of water that the soil may be able to accept before becoming saturated. The amount of pore space and its continuity also influences the rate at which moisture may move through the soil. Other parameters that affect soil hydraulic properties include the type of clay mineralogy, gravel content and depth to an impermeable soil layer. To minimize the risk of waterlogging soils should have a high capacity to accept and transmit water. Increased risk of waterlogging may result from cultivation at the wrong soil moisture content resulting in a cloddy soil structure, compaction from livestock or vehicles, smearing of the clay layer by cultivation implements. Figure 3 identifies areas of Tasmania with soils that are vulnerable to waterlogging (also refer to https://maps.thelist.tas.gov.au/listmap/app/list/map?bookmarkId=383124 for interactive map on LISTmap).

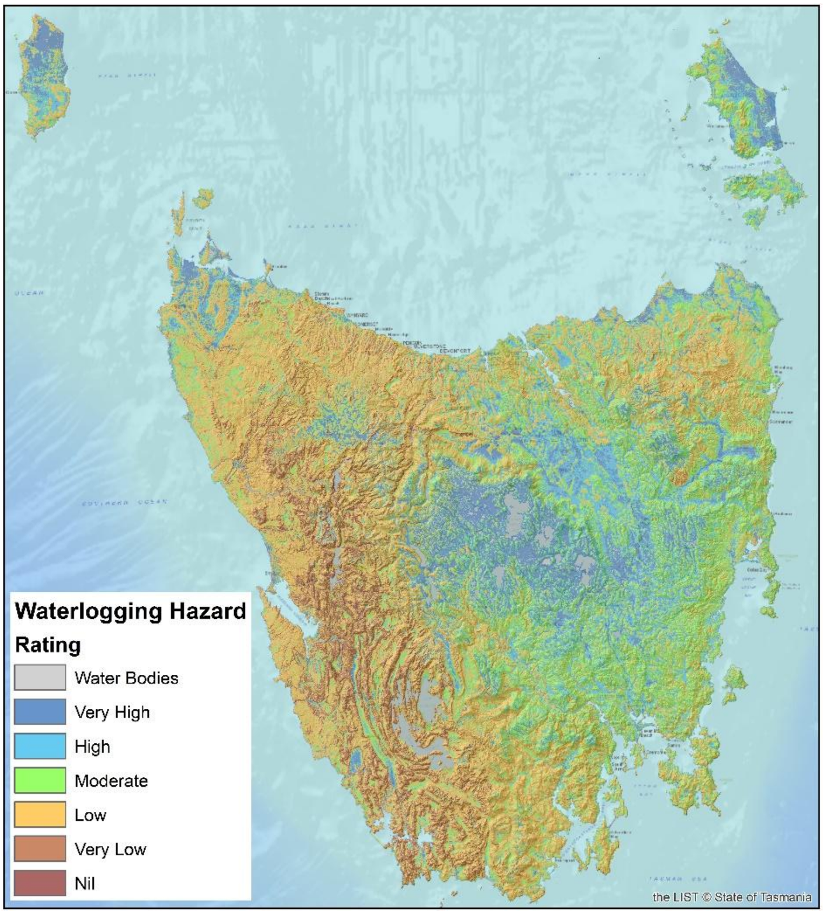

Figure 3. Waterlogging hazard map of Tasmania.

Waterlogging may also result from an excess application of water. This may occur due to topographic constraints (being located in a low lying position, for example), run-off from upslope or flooding from streams and drains. It may also be a result of excessive application from irrigation, combination of irrigation and antecedent rainfall or rainfall (or irrigation) intensities greater than the ability of the soil permeability to remove excess water. Management options for waterlogging are somewhat dependent on the cause of the waterlogging and the nature of the soil.

Management Options for reducing waterlogging

The severity, depth, extent and reasons for impeded drainage will determine the need for and nature of any drainage works that may be necessary. Management options for reducing waterlogging are diverse. The importance of ensuring good irrigation management has been discussed earlier in this document (see page 5). Good irrigation management means not only managing the volume and rate of irrigation but also being aware of soil moisture conditions as well as pre- and post-irrigation weather conditions, current soil moisture status and crop water needs. Other management techniques depend upon the cause of waterlogging. Is the soil compacted, for example, in which case ripping, building organic matter content, using crop management to break up the soil, and minimum till operations to reduce traffic could all be considered.

Alternatively, installing soil drainage may be considered a more appropriate option. This may take two forms: either surface drains that typically intercept overland flow before it reaches a site susceptible to waterlogging, or subsurface in the form of mole drains or slotted ag pipe. Again, the technique used will depend upon the cause of waterlogging and the nature of the soil. Sandy soils, for example, would be unsuitable for mole drains as they tend to collapse easily. Subsurface drains may be unsuitable in sodic soils as the concentrated water flow may lead to erosion in the form of tunneling (see later in this report). Whatever the drainage method used it likely that the services of a drainage expert will be required as design of the drainage network is key to its success. Soil hydraulic properties such as soil permeability, together with an understanding of volumes of water to be removed, rate at which water can be removed, depth to which soil drainage needs to be improved (depending on crop rooting depth) are all essential in determining the depth to which drains or pipes should be installed, dimensions of pipes and drains and the spacing between pipes and drains to ensure adequate drainage. Outfall and disposal of drained water is also an important consideration and the whole drainage operation may be further influenced by economic constraints.

Principles for drainage design and management of waterlogged soils

- Understand the purpose of drainage (surface or sub-surface? Capturing only excess irrigation water or 'other' water?) and determine the cause of impeded soil drainage;
- Determine the suitability of the site for drainage;
- What are the design criteria? Determined by maximum volume of water to be removed, soil hydraulic properties (eg. soil permeability) that are governed by soil texture, structure and chemistry, irrigation properties (water quality and application rates), topography and crop rooting depth requirements;
- Good irrigation efficiency means reduced need for soil drainage;
- Environmental considerations - quality (and quantity) of drainage water (is it saline? Does it contain leached nutrients?), how (and where) will it be disposed of?
- Avoid drainage that will significantly modify natural drainage systems without adequate investigation of impacts, including off-site impacts;
- Importance of catchment management approach to drainage in some areas where many individual property drainage plans might have a wider environmental impact;
- Engineering factors – type of drainage system, drain layout, drain size and shape, materials;
- Consider employing the expertise of a qualified drainage engineer who should have a good understanding of soil hydraulic properties (soil moisture storage and conductivity), irrigation systems, crop water demands and local climate implications.

Climate change, irrigation and the role of the irrigation manager

With predicted climate change scenarios the expectation is that more frequent high intensity rainfall events may be anticipated (see: http://www.dpac.tas.gov.au/divisions/climatechange/climate_change_in_tasmania/impacts_of_climate_change). Drainage design needs to incorporate management of these high intensity rainfall events within an irrigated farming system as climate change may bring with it an increased risk of soil saturation at times when crops are sensitive to waterlogging. This will require incorporation of rainfall risk assessments into drainage design.

Irrigation managers aim to use water as efficiently as they can, and thereby improve farm productivity. To do this, they must match the irrigation system, crop requirements and management practices to the farm's soil and water resources.

Knowledge of hydraulic properties of the soil (and how they might change across a paddock) will enable design of appropriate drain types, size, depths and spacing. Factors such as soil hydraulic conductivity, depth to impermeable layer, depth to water table and rate of water removal assist in designing suitable drainage system that will remove water to adequate depth.

Best Management Practice Guidelines for Soils Vulnerable to Salinity under Irrigation

What is Soil Salinity

Salinity is the accumulation of salts, typically sodium chloride (NaCl) in the soil to levels that affect the productive capacity of that soil. Salinity can occur naturally, known as primary salinity, or be a result of human intervention through vegetation clearing, changes to groundwater recharge or irrigation practices (secondary salinity). Sometimes these changes may be some distance from where the salt expression ultimately occurs. While salinity is a major issue in many areas of Australia, Tasmania is fortunate in that it has only limited extents of salt affected land and these are generally confined to areas with less than about 750mm rainfall per annum – north, central and southern Midlands, Bothwell-Hamilton area and Richmond-Coal River Valley. While the total area of potentially affected land is only about 74000ha, or 3% of Tasmania's agricultural land, in some agricultural areas it can be 5-8%.

Much of the salt originates from weathered rocks rich in sodium minerals although some may come in from rainfall. The salt is leached from the rocks as they weather and often remains in the soil profile or in solution in soil or groundwater. Where moisture levels are reduced through evaporation, salt is deposited and accumulates in the soil at or near the ground surface. In higher rainfall areas there is typically sufficient rainfall to remobilize the salt, washing it back down through the soil profile or out into creeks and rivers were it is further diluted. Where saline groundwater occurs within about 2m of the surface capillary rise, the ability of the soil to wick moisture up through the profile, can raise saline water towards the surface where evapotranspiration may further concentrate and deposit the salt within the root zone of crops. Changes in landform that result in increased proximity of groundwater to the ground surface may also give rise to expressions of salinity. Thus land adjacent to water courses or in footslope locations are prime areas for potential salinity development.

Applications of water through irrigation significantly alter the natural hydrological system of an area and this can further contribute to salinity on and off site. Irrigation salinity is often a result of over-irrigation, inefficient use of water or poor soil drainage. Salinity may develop if excess irrigation water leaks through the soil to a saline groundwater system. Similarly, if water collects and ponds on the ground surface, there is the potential for leakage to groundwater or evaporation resulting in accumulation of any salts that might be dissolved in the water.

Management of soil salinity in irrigation farming systems is primarily about irrigation management and water-use efficiency. To achieve good irrigation management it is important to understand your soils, their hydraulic properties and how they will respond to irrigation. In determining the suitability of an area for irrigation it is important to be aware of the depth to, and quality of, any perched water table that may be recharged by leakage of irrigation water into the groundwater system. Knowledge of the quality of water being used for irrigation is also important as, in a deficit irrigation system like that used in Tasmania, use of saline water can lead to the accumulation of salts in the soil as the water is used by plants. Over time even small amounts of salt can accumulate to levels detrimental to crop growth. Achieving high water-use efficiency requires a knowledge of crop water needs, soil moisture characteristics and irrigation technology (see section on Irrigation Management).

As with other forms of soil degradation understanding the causes of salinity is important in determining the appropriate management responses.

Measuring and monitoring for salinity

Salinity is typically measured in the field measuring the electrical conductivity a 1:5 soil:distilled water solution using a salinity meter. This measure is typically referred to as $EC_{1:5}$. In the laboratory a sample of soil is saturated and the excess water then drawn off and the conductivity of this water sample is measured (known as EC_{se}). Units of conductivity measurement are generally dS/m but occasionally other units are used. Table 6 provides a means of converting between different units.

Table 6. Converting between salinity units.

	dS/m	**mS/m**	**µS/cm**	**mg/L (ppm)**
1 deciSiemen per metre (dS/m)	-	1	1000	670
1 milliSiemen per cm (mS/cm)	1	-	1000	670
1 microSiemen per cm (µS/cm)	0.001	0.001	-	0.67
1 milligram (ppm) per litre (mg/L or ppm)	0.0015	0.0015	1.5	-

$EC_{1:5}$ and EC_{se} are not the same! EC_{se} is the standard measure of salinity and converting $EC_{1:5}$ to EC_{se} requires a knowledge of the soil texture and texture-dependent conversion factors are then used to change $EC_{1:5}$ to EC_{se}. These estimates of EC_{se} are referred to as EC_{ese}. Texture conversion factors are presented in Table 7.
EC_{ese}=$EC_{1:5}$ x texture conversion factor.

Table 7. Texture conversion factors for salinity.

Texture	Factor
Sand	17
Sandy loam	14
Loam, silt loam, sandy clay loam	10
Clay loam, silty clay loam, sandy clay, silty clay	9
Light clay	8
Medium clay	7
Heavy clay	6

Source: Slavich and Petterson 1993

Monitoring for salinity needs to consider both soil and groundwater salinity (and possibly also monitoring of irrigation water salinity and stream and drain salinity). Soil samples for testing soil salinity should be taken from various depths to determine whether there is any salt accumulation within the soil profile. Groundwater salinity monitoring may require the installation of a piezometer (a piece of slotted plastic pipe extending down to the water table that enables a water sample to be collected and also the depth to water table to be measured). Tables 9 and 10 indicate standard classes of water and soil salinity.

Table 8. Water quality classes for salinity (Taylor 1993)

Water Quality Class	Salinity Level (dS/m)
Fresh	<0.8
Marginal	0.8-1.6
Brackish	1.6-4.8
Saline	>4.8

Table 9. Soil classes.

Soil ECse (dS/m)	Salinity rating
0-2	Non saline
2-4	Slightly Saline
4-8	Moderately saline
8-16	Highly saline
>16	Extremely saline

Management principles to avoid development of salinity under irrigation farming systems

As discussed above, irrigation salinity may result from inefficient irrigation practices leading to groundwater recharge and/or through the use of poor quality irrigation water allowing salts to build up in the soil profile. Ensuring efficient irrigation management techniques and using good quality irrigation water will go a long way to mitigating against the development of soil salinity under irrigated farming systems. Core principles for salinity management are:

- Assess your salinity risk
    - Assess the biophysical hazards (features of the landscape that may contribute to salinity) and/or refer to the DPIPWE salinity hazard map on TheLIST (see Figure 4 or https://maps.thelist.tas.gov.au/listmap/app/list/map?bookmarkId=383137 for interactive map on LISTmap);
    - Consider influence of management practices on salinity risk;
    - Understand the current status of salinity in your soils/irrigation water and how it might change under irrigation.
- Minimise potential recharge to the groundwater system by
    - Ensuring you have an appropriate and well-designed irrigation system;
    - Avoiding over irrigation – use efficient irrigation practices;
    - Using deep-rooted crops to maximize water use;
    - Minimize fallow periods that facilitate water infiltration and groundwater recharge;
    - Avoid unnecessary cultivations that aid infiltration and potentially aid groundwater recharge;
    - Mulch to reduce soil surface evaporation;
    - Monitor depth to and quality of groundwater;

- Monitor for soil salinity regularly and often.

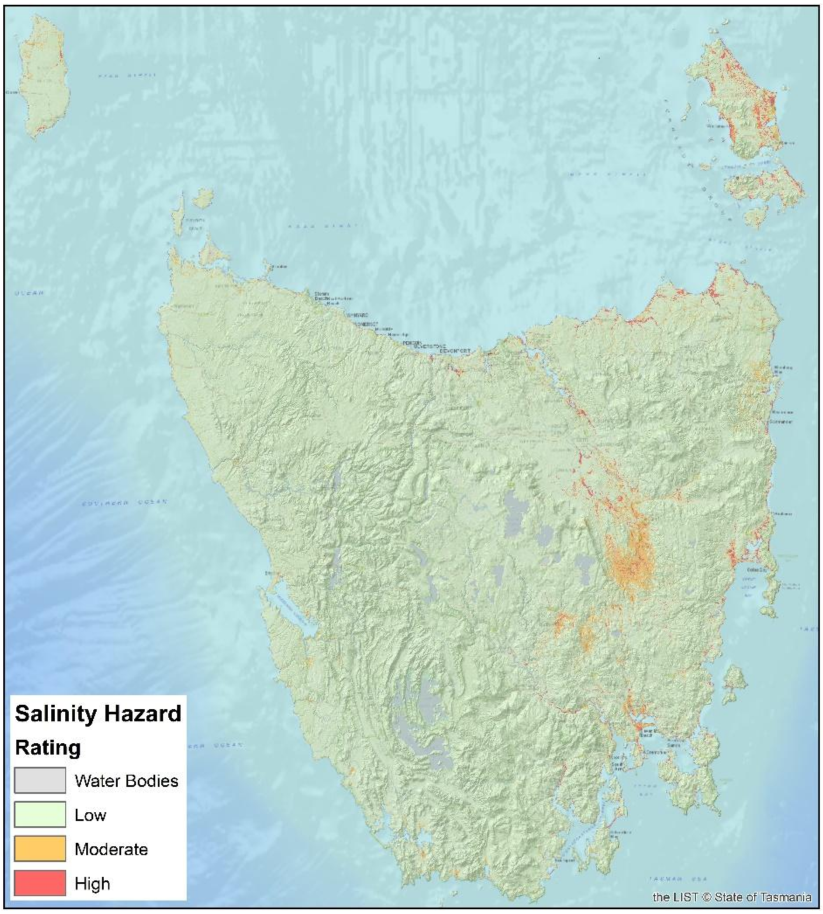

Figure 4. Salinity hazard map of Tasmania.

Best Management Practice Guidelines for Soils Vulnerable to Sodicity under Irrigation

The *Soils Vulnerable to Sodicity* map identifies areas of Tasmania where soil sodicity is predicted to be an issue and will require implementation of appropriate management techniques to minimize the risk of soil degradation (see Figure 5 or https://maps.thelist.tas.gov.au/listmap/app/list/map?bookmarkId=383139 for interactive map on LISTmap). The depth to and degree of sodicity typically defines the severity of the problem and the intensity of mitigation measures that might need to be implemented to reduce sodicity hazard.

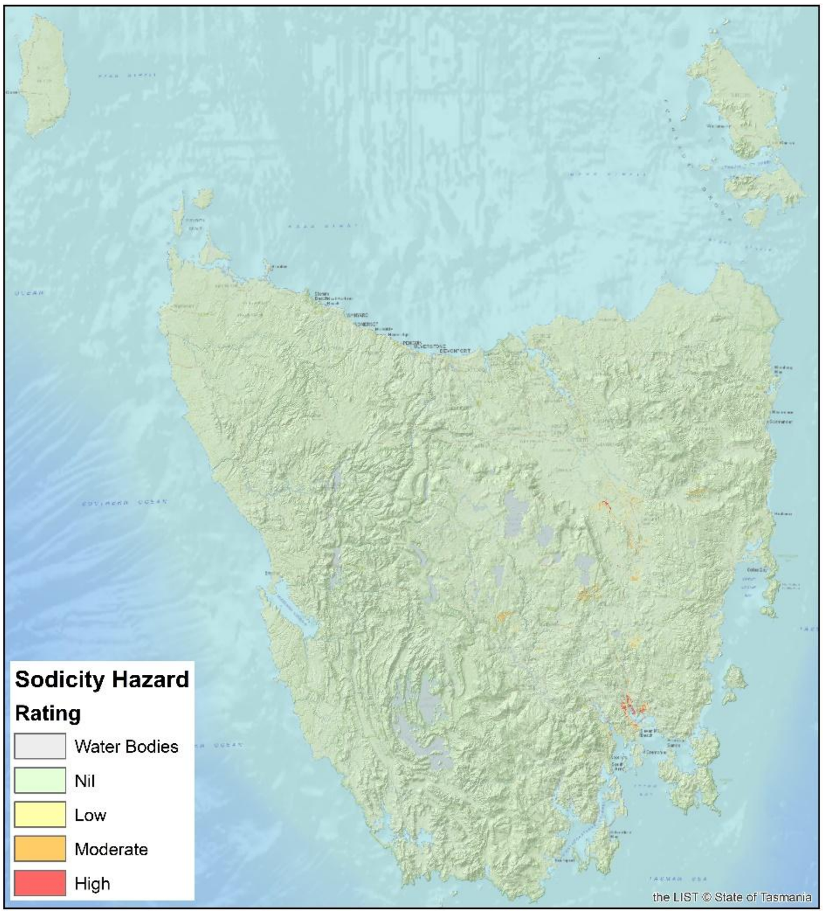

Figure 5. Sodicity hazard map of Tasmania.

What is Soil Sodicity and why is Na in the soil a problem?

Soil sodicity occurs where the sodium (Na) ions make up 6% or more of all cations attached to soil particles. That is, the Exchangeable Sodium Percentage (ESP) is greater than 5%.

Not all soils are susceptible to sodicity. Quartz grains, forming the vast majority of sand sized particles in a sandy soil, are essentially electronically neutral and do not provide any sites for Na ions to bind to. Clay soils on the other hand, with their more complex, layered structure, have many exchange sites and are more capable of binding soil nutrients and sodium ions alike. In addition to suitable exchange sites, a source of Na ions is required to create the levels of sodicity necessary to classify a soil as sodic. Often this source of Na ions is the parent material from which the soil has formed. Many soil forming minerals contain Na ions and these are released as the mineral is weathered. Other sources might include saline groundwater, or even irrigation water, when evaporation of this water leads to a concentration of Na in the soil.

Compared to soils high in magnesium or calcium soils containing sodium are susceptible to structure decline when they get wet. At the microscopic level clay particles are comprised of layers of minerals like pages in a book. These layers retain a weak electrical charge and it is this that gives the soil its ability to retain soil nutrients including Na ions. These Na ions also have a strong attraction for much larger water molecules and when the water molecules are also adsorbed into a soil the soil expands, increasing distance between mineral layers, reducing the ionic bonding between molecules and causing a breakdown of the soil structure. These finer particles block soil pores, pathways for air and water movement through the soil, increase soil density making it harder for roots to develop, and may form surface crusts as the soil dries reducing seedling emergence and germination. Under the right conditions these impacts can be very severe resulting not only in reduced crop yields but also increased risk of erosion by water. This is due to both the crusting effect that reduces surface infiltration, thereby increasing run-off, and the physical breakdown of soil aggregates into smaller particles that can more easily be eroded and transported.

Identifying Sodic Soils

Identifying sodic soils is relatively straightforward. In their natural state sodic soils may exhibit poorly developed or coarse structure. In wet conditions water may pond on the surface for long periods due to the blocking of pores as the soil disperses. A surface crust may be apparent and rills may develop as a result of run off. Tunnel erosion is often evident where subsoils are sodic rather than topsoil. If a soil pit is excavated sodic subsoils often show a domed structure. An easy field test for soil sodicity is to take a small piece of air dry soil and drop it into distilled or rain water and leave to stand without disturbance for an hour or so. If the soil forms a cloud then the soil is likely to be sodic. In the laboratory soil sodicity is determined by calculating the relative proportion of Na ions compared to the soil's cation exchange capacity (the proportion of sites available to which cations might attach) thus:

ESP=Exchangeable (Na/CEC)x100

Most of Tasmania's sodic soils have sub-surface rather than surface sodicity.

Management Options for Sodic Soil

Managing soil sodicity begins with knowing if your soil is sodic or not (using a lab test or the simple field dispersion test mentioned above) and the depth at which any sodic layer begins and just how sodic that layer is.

If the sodic layer is a subsoil layer then management can focus upon not disturbing the sodic layer by minimizing cultivation to reduce risk of mixing with non-sodic topsoil and thereby increasing the risk of soil crusting and reduced germination. If possible consider shallower cultivation, direct drilling or minimum cultivation operations. If deep ripping to breakup subsoil compaction applications of 5-10t/ha of gypsum directly into rip lines has been shown to be beneficial on sodic soils.

If the topsoil is sodic then building organic matter levels and applications of gypsum will afford some short term benefit. Gypsum is a calcium sulphate compound and works by replacing the sodium ions on clay particles with calcium (Ca) ions. This reduces the ESP and reduces swelling and dispersion of soil aggregates. Gypsum may also assist with shallow subsoil sodic layers but the improvements will take longer to become apparent depending on the depth to the sodic layer. For sodic layers below about 25cm there may not be any benefit to productivity in applying gypsum. Applying gypsum into rip lines can benefit sub soil sodicity. Lime can also assist in reducing sodicity but, being less soluble than gypsum, may require higher application rates. For sodic layers of ESP 6-10% application rates of 2-5 t/ha are appropriate. For ESP greater than 10% 5-10 t/ha of gypsum may be necessary.

As gypsum is a reasonably soluble mineral it is leached away through the soil over time and reapplications may be needed every few years to maintain the benefits.

Irrigation and Sodic soil Management

Dispersion of sodic soils in water is controlled by the relative concentration of salts (Na ions) in the soil compared to that in water. Reducing dispersion, and thereby minimizing the risk of structure degradation, can be achieved by reducing the salt (Na ion) concentration in the soil OR by increasing the salt concentration in the water. Thus theoretically, in order to minimize soil structure decline in sodic soils under irrigation, it is better to use poorer quality (slightly saline) water than high quality water. However, great care needs to be taken that using slightly saline water to combat sodicity does not lead to a buildup of salts in the soil thereby creating a salinity problem. In Tasmania most irrigation is based upon deficit irrigation levels, ie only sufficient irrigation water is applied that can be used by the crop or evaporated under the existing climate conditions. Using saline irrigation water in these circumstances is high risk as salt is likely to build up in the soil and there is no mechanism for flushing it away.

Dispersion of soil particles in sodic soils can give rise to poor soil drainage through the blocking of soil pores and slower rates of soil moisture removal. This can adversely impact on the drainage of soils – an important soil property when considering suitability of the soil for irrigation. The depth and severity of sodicity may influence drainage options for removing excess water under irrigation. These factors should be considered when planning an irrigation development.

Principles for Sodicity Management

- Understand the depth to, and severity of any sodic layers;
- Minimise cultivation of sodic layers unless it is a surface layer that needs breaking up to reduce crusting;
- Consider applications of gypsum to lower the ESP;
- Use of deep rooting perennials will assist in the breakdown of massive soil structure often occurring in sodic soils;
- Avoid using good quality water for irrigating sodic soils as this may increase the consequences of dispersion;
- Building soil organic matter may help reduce the impacts of sodicity;
- Be aware that sodicity and salinity often go hand-in-hand and therefore both may need to be managed for.

References

Chilvers, WJ (1996) Managing Tasmania's Cropping Soils –a practical guide for farmers. DPIPWE, Tasmania.
http://dpipwe.tas.gov.au/Documents/Managing-Tasmanias-Cropping-Soils-2000.pdf

Hamlet, AG (ed)(2002) Soil Management – A guide for Tasmanian Farmers. DPIPWE, Tasmania.
http://dpipwe.tas.gov.au/Documents/Soil-Guide.pdf

Cotching, B (2009) Soil Health for Farming in Tasmania.
http://www.utas.edu.au/__data/assets/pdf_file/0005/386762/Bill_Cotching_Soil-Health-for-Farming-in-Tasmania.pdf

Grose, CJ (ed) (1999) Guidelines for the Classification of Agricultural Land in Tasmania. 2nd Edition, DPIPWE, Tasmania.

Cotching, WE, Cooper, J, Sparrow, LA, McCorkrell, BE, Rowley, W (2002a) Effects of Agricultural management on Tenosols in Northern Tasmania. *Aust. J. Soil Res. 40, 45-63.*

Cotching, WE, Cooper, J, Sparrow, LA, McCorkrell, BE, Rowley, W (2002b) Effects of Agricultural management on Dermosols in Northern Tasmania. *Aust. J. Soil Res. 40, 65-79.*

Cotching, WE, Cooper, J, Sparrow, LA, McCorkrell, BE, Rowley, W (2002c) Effects of Agricultural management on Sodosols in Northern Tasmania. *Aust. J. Soil Res. 39, 711-735.*

Sparrow, LA, Cotching, WE, Cooper, J, Rowley, W (1999) Attributes of Tasmanian Ferrosols under different agricultural management. *Aust. J. Soil Res. 28, 825-839.*

www.naturalresources.sa.gov.au/files/sharedassets/south_east/water/irrigation/150629-irrigation_best_management_practices.pdf

http://dpipwe.tas.gov.au/agriculture/land-management-and-soils/soil-management/irrigation/wise-watering-irrigation-management-course

https://maps.thelist.tas.gov.au/listmap/app/list/map

Slavich, PG, Petterson, GH (1993) Estimating the electrical conductivity of saturated paste extracts from 1:5 soil: water suspensions and texture. *Aust. J. Soil Res.* **31**: 73-81

Taylor, S (1991). Dryland salinity introductory extension notes. Department of Conservation and Land Management, NSW

http://www.soil.ncsu.edu/certification/manual/slides/chapter5a/img14.html

http://www.environment.nsw.gov.au/resources/salinity/Book2DrylandSalinity.pdf

Other useful websites

- http://www.dpi.nsw.gov.au/content/agriculture/resources/soils/erosion/soil-erosion-factsheets
- http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/erosion
- http://dpipwe.tas.gov.au/agriculture/land-management-soils/soil-management/soil-erosion/soil-erosion-control
- http://www.dpi.nsw.gov.au/content/agriculture/resources/soils/guides/soilpak/vegetable
- http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0009/127278/Sodic-soil-management.pdf
- http://www.dpi.nsw.gov.au/content/agriculture/resources/soils/sodic
- https://www.qld.gov.au/environment/land/soil/soil-properties/sodicity/
- https://www.agric.wa.gov.au/water-erosion/management-dispersive-sodic-soils-experiencing-waterlogging
- http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/sodic_soils
- http://dpipwe.tas.gov.au/Documents/DPIW_DSM_Manual_April2009.pdf
- http://www.dpi.nsw.gov.au/content/agriculture/resources/soils/salinity
- http://www.environment.nsw.gov.au/salinity/solutions/irrigation.htm
- http://research.wineaustralia.com/wp-content/uploads/2012/11/2011-FS-Salinity-Management.pdf
- https://www.qld.gov.au/environment/land/soil/salinity/management/
- https://publications.qld.gov.au/storage/f/2013-12-19T04%3A25%3A59.544Z/salinity-management-handbook-foreword.pdf
- https://grdc.com.au/uploads/documents/GRDC_Canola_Guide_All_1308091.pdf
- http://www.ccmaknowledgebase.vic.gov.au/shkb/brown_book/32_Salinity.htm#Practice
- https://www.dpaw.wa.gov.au/images/conservation-management/salinity/salinity-strategy.pdf
- http://dpipwe.tas.gov.au/agriculture/land-management-soils/salinity/tasmanian-salinity-strategy
- http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/210756/Increasing-soil-organic-carbon.pdf
- http://www.ccmaknowledgebase.vic.gov.au/shkb/brown_book/37_Soil_Carbon.htm
- http://dpipwe.tas.gov.au/agriculture/land-management-soils/soil-management/soil-organic-matter
- http://agriculture.vic.gov.au/agriculture/dairy/managing-wet-soils
- https://www.agric.wa.gov.au/crops/production-postharvest/soil-management
- http://soilquality.org.au/factsheets/waterlogging-tas
- http://www.extension.umn.edu/agriculture/water/planning-a-subsurface-drainage-system/
- http://www.saiplatform.org/uploads/Library/%23516-Bestmanagementguidelinesforsustainableirrigatedagriculture.pdf
- http://ahr.com.au/wp-content/uploads/2015/03/Managing-water-for-yield-and-profit_Training-guide.pdf
- http://www.naturalresources.sa.gov.au/southeast/water-and-coast/Irrigation-management/Irrigation-and-soils
- http://agriculture.vic.gov.au/agriculture/farm-management/soil-and-water/irrigation/about-irrigation
- https://www.naturalresources.sa.gov.au/files/sharedassets/adelaide_and_mt_lofty_ranges/land/best-practice-land-management-guidelines-small-grazing-properties-gen.pdf
- http://www.cottoninfo.com.au/publications/irrigated-wheat-best-practice-guidelines-cotton-farming-systems