Chapter 16 — Irrigation management

Key issues in sustainable irrigation are:

- preventing excessive salt accumulation in the root zone
- maintaining soil structural stability
- minimising excess drainage of water below the root zone
- maintaining crop or plant productivity
- minimising off-site effects.

Whether the landholder is considering implementing irrigation or adjusting irrigation regimes, the process of investigating options is basically the same:

- Assess the quality of the water currently being used or proposed for irrigation.
- Consider characteristics of the soils in the area proposed for irrigation—in particular, soil structural stability and permeability.
- Consider characteristics of plant species proposed for the irrigated area—in particular, salt tolerance (many species are listed in the appendix ***Plant salt tolerance*** data page 124).
- Determine the likely leaching fraction of the soil and the consequent root zone salinity and amount of drainage below the root zone (which can be determined using the computer software package SALFPREDICT, described in the appendix ***Useful software packages*** page 141).
- Estimate the effects of irrigation water sodicity on soil behaviour.

(Procedures for investigating these issues are discussed in some detail in ***Soils*** page 58 and ***Waters*** page 65.)

Variation in the choice of crop, soil characteristics and water quality makes irrigation management decisions quite complex. The computer package SALFPREDICT is designed to consider salinity, sodicity and soil and plant factors together (discussed in the appendix ***Useful software packages*** page 141).

Irrigation management to minimise watertable rise

In irrigation areas that are supplied with surface water, efficient water management is essential to prevent watertable rise. Because some leaching below the root zone is inevitable, monitoring of water levels is an essential aspect of irrigation management.

Good hydrological information is essential when planning and developing irrigation areas. When gathering and using this information, the following are important:

- Restrictions to water movement through the landscape must be identified and incorporated into plans for controlling the watertable (refer to ***Landform feature identification*** page 39).
- Areas with highly permeable soils (which contribute to high rates of accession to the watertable) must be identified and considered for specific irrigation management or exclusion from the irrigation scheme.

Accessions to watertables can be reduced in three ways:

- For surface water supplies with good quality water (see ***Irrigation*** page 81) on permeable soils, more efficient water management techniques, such as trickle or microsprinkler, can be used to avoid excess water moving below the root zone. In groundwater-based systems accessing water in an unconfined aquifer, this is less of a problem, as excess drainage moves to the groundwater where it becomes available again for irrigation.
- Under flood or furrow irrigation, surface levelling promotes more uniform soil wetting on clay soils, so levelled areas can be irrigated for shorter periods for the same effect. Levelling can improve surface drainage in flat areas, assisting runoff of excess water from the soil surface.
- Selecting a water application system which is appropriate for the permeability of the particular soil is also important. With permeable soils, sprinkler or trickle irrigation is more satisfactory than flood irrigation in most cases. With heavy cracking clay soils, flood or furrow irrigation, managed to limit tail drain losses, is more efficient for wetting the soil.

In surface water schemes, seepage from supply channels can significantly contribute to watertable rises. To reduce this problem, channels can be lined (often an expensive option), or pipes or fluming can be used to distribute the water on-farm.

Subsoil drainage or watertable pumping and water reuse can be used to control high watertables. However, several factors need to be considered regarding drainage, such as whether there is an adequate height difference between the watertable and the drain outlet, soil hydraulic conductivity and its implications for drain spacing, options for disposing of drain effluent, water quality, and aquifer transmissivity. (Refer to ***Engineering methods*** page 110 for a discussion of these issues.)

Marginal quality irrigation waters

The best approach is to match soils, irrigation waters and crops to minimise negative impacts of irrigation on soils. In order to implement this, it is necessary to have an accurate assessment of water quality. (Assessing water quality is covered in ***Irrigation*** page 81.)

Where it is not possible to match all these factors, a number of irrigation management practices can be used to minimise the effects of marginal quality irrigation water on soils and crops. These practices include changing the frequency, duration and method of irrigation, judicious timing of leaching irrigations, mixing irrigation water supplies, and cultural practices including soil amendments. These are outlined below and described in detail by Ayers and Westcot (1976). Shaw et al. (1987) describe the limitations of several irrigation management approaches in practice.

Salinity and sodicity are the two major issues with marginal quality water use. Management practices to minimise the effects of such waters are outlined in the following sections.

Saline water

Irrigate more frequently

Provided the root zone is wet, more frequent irrigation reduces plant water stress, dilutes the soil solution, and sometimes increases leaching of salts. Increasing irrigation frequency is appropriate where irrigation water is available on demand and soils are permeable. However, the cost of irrigation may also be increased, as may be the likelihood of watertable rise.

Use extra water to control salinity by leaching

Two options are available here:

- In soils with good drainage and where the watertable is not high, maintain salt balance throughout the season by applying extra water each irrigation for leaching.
- Allow salt to accumulate during the growing season and then implement specific leaching irrigations (that is, apply extra water during periodic preplanned irrigations). Water use is more efficient, but some yield loss may result from salt accumulation. In all soils other than slowly permeable soils, leaching in small amounts is more efficient than ponding. In slowly permeable soils, ponding is more efficient. Timing of leaching irrigations depends on crop salt tolerance and water salinity. For annual crops, pre- or post-crop irrigation is preferred. Pre-cropping irrigation will assist germination by leaching surface salt. Cropping in cooler months or, alternatively, irrigating to coincide with a period of major seasonal rainfall will contribute to greater leaching. For perennial crops, leaching irrigations during dormant periods are more effective, since less evapotranspiration occurs.

With slowly permeable soils, the use of marginal quality water for leaching may contribute to higher soil salinity levels, because more salt can be added to the soil than is removed during leaching even though there is an increase in the leaching due to flocculation by the salts. In this situation, seasonal rainfall will provide leaching. In dry years, salinity effects on plants will be more severe.

Choose the best irrigation method for the conditions

The method of irrigation used can affect salt accumulation.

- Flood irrigation provides an even application of water but can be wasteful, particularly in a high-frequency irrigation scheme. In cracking clay soils, flood irrigation provides good recharge of soil water and some potential for leaching if the soil is cracked before irrigation.
- Furrow irrigation contributes to salt accumulation in adjacent rows through capillary rise and evaporation from the highest parts of the ridges. Thus planting in the furrow or on the side of larger hills will reduce salt concentration. (See ***Mounding*** page 101.)
- Sprinkle irrigation provides good control and maximum flexibility. However, it can cause leaf damage (burn) and salt precipitation on leaves. Some water is lost through evaporation, which increases the salinity of water on the leaves. Both leaf damage and evaporation can be reduced by sprinkling at night. Precipitates on leaves can be reduced by increasing the sprinkler rotation speed. In cracking clay soils, the lower application rate of sprinkle irrigation can cause surface sealing and greatly reduce soil wetting.

- Trickle irrigation is efficient but contributes to salt accumulation in the soil surface and at the edge of wetted areas. Under rainfall, salts accumulated at the soil surface can be leached down into the root zone in sufficient concentrations to kill vegetation. These effects can be reduced by applying a surface mulch to minimise evaporation or by burying the emitter at some depth in the root zone. Microsprinklers are an alternative option.

Some species can tolerate higher salinity levels in the soil than in water which is applied to the leaves. This is specifically relevant to crops under irrigation. Methods for managing this situation and being able to continue to irrigate crops with marginally saline waters (in relation to each crop species) include irrigating below the leaves and irrigating at night (to reduce salt on the leaves left by rapid evaporation during the day). Some crops for which information is available are listed in Table 45.

Mix water supplies

Mixing water supplies can reduce salinity hazard if good quality water is available in addition to the marginal quality water. However, mixing a saline water with good quality water is not necessarily a good strategy. If the saline water is of higher salinity than the plant can tolerate, diluting it with a less saline water is a waste because once the threshold salinity is reached, the plant cannot use the water.

Two options are preferred for using good and marginal quality water supplies for irrigation:

- Alternate applications of marginal quality water with applications of good quality water, when available. This will maintain a lower salt balance, provided sodicity is not a problem. With species that have differing levels of salinity tolerance depending on stage of growth, water quality can be matched to stage of growth.
- Alternate salt-tolerant and salt-sensitive crops with different irrigation waters. This option is preferred where good quality water is available and seasonal rainfall promotes leaching.

Sodic water

Sodic irrigation waters generally result in soil dispersion with consequent soil surface sealing, crusting, erosion, poor water entry and poor seedbeds. This dispersion is reduced by the salinity level in an irrigation water but problems develop under heavy rainfall when salts are leached from the soil surface. Points listed above under irrigating with marginally saline waters are generally relevant to irrigating with marginally sodic waters, in addition to the following points.

Table 45. Relative tolerance of sprinkled crops to salinity impinging on the leaves or roots. Salinity levels are expressed as the electrical conductivity of the irrigation water (EC_{iw}) (after Maas 1985). Table used with kind permission of E. V. Maas and Kluwer Academic Publishers (*Plant and Soil*, 89, pp. 273–84, 'Crop tolerance to saline sprinkling water').

Common name	Scientific name	Salinity threshold	
		Max. EC_{iw} [1] (dS/m)	Max. EC_{iw} [2] (dS/m)
Grain crops			
Barley	*Hordeum vulgare*	1.0–2.0	5.3
Corn	*Zea mays*	1.0–2.0	1.1
Cotton	*Gossypium*	3.0–6.0	5.1
Safflower	*Carthamus tinctorius*	1.0–2.0	
Sesame	*Sesamum indicum*	1.0–2.0	
Sorghum	*Sorghum bicolor*	1.02–2.0	4.5
Sunflower	*Helianthus annuus* sp.	14–16	
Fruit			
Almond	*Prunus dulcis*	< 0.5	1.0
Apricot	*Prunus armeniaca*	< 0.5	1.1
Citrus	*Citrus* sp.	< 0.5	1.1
Grape	*Vitis* sp.	0.5–1.0	1.0
Plum	*Prunus domestica*	<0.5	1.0
Strawberry	*Fragaria*	2.0–4.0	0.7
Heavy vegetables			
Potato	*Solanum tuberosum*	0.5–1.0	1.1
Sugarbeet	*Beta vulgaris*	3.0–6.0	4.7
Pasture			
Lucerne	*Medicago sativa*	1.0–2.0	1.3
Vegetables			
Cauliflower	*Brassica oleracea*	3.0–6.0	
Cucumber	*Cucumis sativus*	1.0–2.0	1.7
Pepper	*Capsicum annum*	0.5–1.0	1.0
Tomato	*Lycopersicon lycopersicum*	0.5–1.0	1.7

Notes
1. Saline waters (primarily NaCl) with EC_{iw} values higher than the threshold are expected to cause foliar injury on crops sprinkled five or more hours each week during the irrigation season. The degree of injury is influenced by the cultural and environmental conditions.

2. Salinity exceeding the threshold is expected to decrease the yield below that of crops irrigated with non-saline water. The relationship, $EC_{se} = 1.5\ EC_{iw}$, was used to express the soil salinity threshold in terms of EC_{iw}, that is, a leaching fraction of 0.15.

Mix water supplies

Mixing available waters to maintain a satisfactory sodicity level can be a viable management option, providing salinity levels are satisfactory.

Apply gypsum

Gypsum (calcium sulfate) can be used as a soil amendment to improve the structure of surface soils and to alleviate some of the adverse effects of high sodicity waters and those with residual alkali (Na_2CO_3). Gypsum improves soil structure by increasing flocculation of clay particles through increased electrolyte concentration and by exchange of calcium for sodium on the exchange complex. This results in better surface soil aggregation and consequently reduced waterlogging and crusting and can improve surface soil drainage. Long-term benefits of gypsum in exchanging for sodium can only occur if the exchanged sodium can be leached out of the profile. Thus on soils with slowly permeable subsoils there will be limited benefits.

Gypsum has a relatively low solubility; it is estimated that no more than 700 kg of surface-applied pure gypsum can be dissolved per megalitre of irrigation water in any one year (Ayers & Westcot 1976)—that is, 100 mm depth of water per hectare. Thus under common conditions (assuming rainfall of 800 mm/yr and irrigation water application of 500–600 mm/yr), an application of around 1 t/ha/yr of pure gypsum could be dissolved. Because of impurities in gypsum, unevenness of distribution and loss from surface runoff, the general recommendation is 2–6 t/ha every year or per two-year period. In some situations, depending on the gypsum responsiveness of a soil, applications of 5 t/ha seem to be more successful in achieving a measurable effect. Gypsum added directly to irrigation water is much more effective than when applied to the soil surface, but the cost of dissolution will increase the overall cost.

The above recommendations depend on soil chemistry. The solubility of gypsum varies with different ions (discussed in ***Basic chemical processes and solubility of salts*** page 74). Thus in some salt-affected soils the solubility of gypsum may be increased, particularly if NaCl is present. (Some helpful notes on gypsum application rates and conversions are provided in ***Notes on gypsum*** page 160.)

Apply other soil amendments

Sulfur application can be useful on sodic soils if there is a high level of calcium carbonate at the soil depth required. Also, sulfuric acid can be used for high alkalinity and residual alkali waters. However, sulfuric acid is not appropriate if calcium or magnesium levels are low since sodicity will remain high. Handling this acid is dangerous.

Irrigate for longer periods of time

A longer duration of irrigation is required with sodic waters since sodic soils have lower infiltration rates and need more time for the water to become wet. Irrigation across slope or recycling taildrain water will help conserve water. Long irrigations, however, can lead to aeration problems.

Choose the best irrigation method for the conditions

Spray irrigation can cause surface crusting and sealing on sodic soils if used during crop establishment without a surface mulch to protect the soil surface. Capillary wetting of hills from furrow irrigation results in less soil slaking and dispersion than spray irrigation.

Protect the soil surface

Medium seedbeds are preferable to fine seedbeds to reduce slaking and dispersion and crusting on irrigation. Adding large quantities of organic matter will help maintain soil structure of some soils and reduce cloddiness.

Reclaim sodic soils using saline water

If the land value is very high and there are advantages in reducing the soil sodicity levels, a reclamation method for sodic soils with very low permeability can be attempted. Using this method, high salt concentration waters are applied initially to flocculate the soil. Once the permeability is raised, the SAR of the water is gradually reduced as the salinity is reduced, resulting in low ESP and improved soil structure. This process needs to be monitored closely.