Information Sheet

5. IRRIGATION

5.1 Irrigation Fundamentals

This information sheet provides an overview of the basic concepts of irrigation. Topics include the soil water balance, crop water use, soil water holding characteristics, irrigation scheduling and irrigation system efficiency and uniformity.

The soil water balance

Irrigation is used to supplement rainfall. Through irrigation, root zone soil water content is maintained within a target range to minimise crop water stress and to maximise the efficiency of irrigation water and rainfall use. Water is removed from the soil by evaporation from the soil surface and by crop water uptake driven by transpiration from the crop canopy. The combined process is called evapotranspiration or crop water use. This only makes up one component of the soil water balance. On its own, this information is not adequate to manage irrigation properly. All the components of the soil water balance need to be accounted for (Figure 1).

Water enters the root zone (inflow) either as rainfall or irrigation and exits (outflow) either as evapotranspiration, runoff or deep drainage past the root zone. Change in soil water content can be determined using this equation:

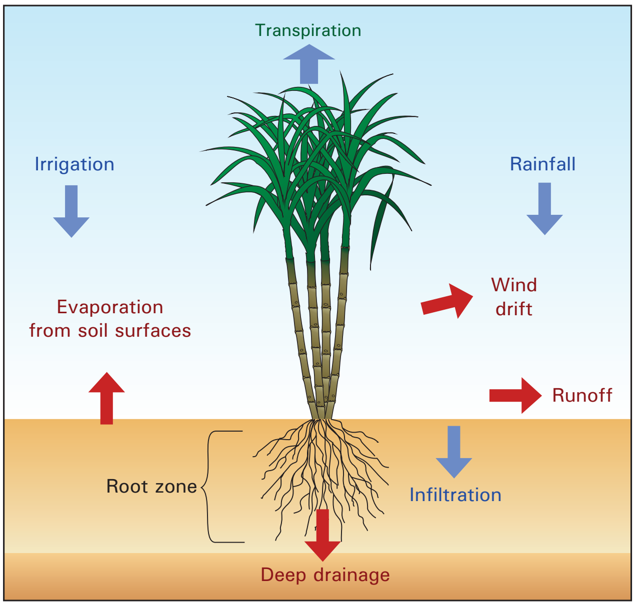
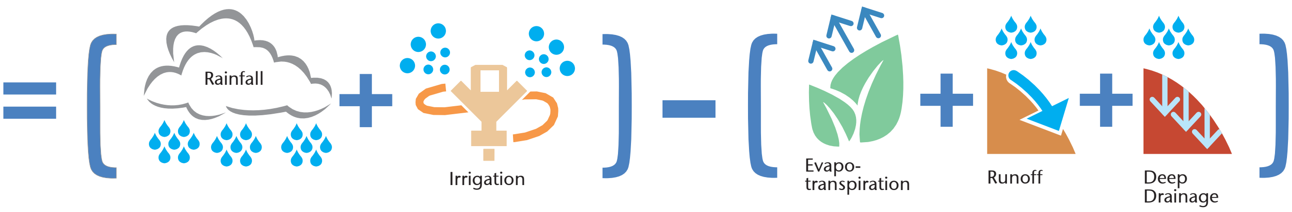


Figure 1. Components of the soil water balance

$$\Delta SWC = \text{Inflow} - \text{Outflow}$$
$$= (R + I) - (ET + Ro + D)$$

Where:

ΔSWC	=	Change in Soil Water Content (mm)
R	=	Rainfall (mm)
I	=	Net Irrigation (mm)
ET	=	Evapotranspiration (mm)
Ro	=	Runoff (mm)
D	=	Deep Drainage (mm)



Crop Water Use (ET)

Transpiration and carbon dioxide absorption for photosynthesis are parallel processes in the plant and this relationship explains the close association with crop yield. ET is driven by four factors:

- *The atmospheric evaporative demand determined by weather conditions (solar radiation, temperature, wind speed and humidity).*
- *The crop canopy (which is the amount of leaf cover as determined by the growth stage of the plant).*
- *The amount of water available to the plant in the root zone.*
- *The wetness of the exposed soil surface.*

Soil in the context of the soil water balance

The soil serves as a reservoir for storing water and nutrients. The depth of the soil profile and the soil texture (sand, silt and clay percentage) determine the water holding capacity of the soil. In the SA sugar industry, water holding capacity is referred to as the Total Available Water (TAW).

If the water applied to the soil, either through rainfall or irrigation, causes the available soil water content to exceed the TAW (i.e. storage capacity), water will be lost from the root zone via deep drainage or runoff. Runoff also occurs when the irrigation application rate or rainfall intensity is greater than the soil infiltration (intake) rate. Since nutrients are also stored in the soil, deep drainage will leach away valuable nutrients from the root zone. The same will be true if runoff causes the erosion of top soil. In some circumstances, deep drainage may be required periodically to leach harmful/unwanted salts from the root zone.

Rainfall and over-irrigation can also bring about saturated conditions. In the long term, saturated conditions are also associated with rising water tables which deposit harmful salts in the soil root zone. The lack of oxygen, migration of microorganisms and detrimental impact on soil structure and soil chemistry collectively reduce the soils water holding capacity and agricultural value.

What is Irrigation scheduling?

Irrigation scheduling is the process of deciding when and how much water to apply. Poor irrigation scheduling can result in either under-irrigation, leading to water stress and reduced yields, or over-irrigation which leads to misuse of water and electricity resources, leaching of expensive fertilisers, erosion of the top soil and anaerobic soil conditions leading to yield reductions. The aim is to maximise beneficial use of water (transpiration) and minimise non-beneficial use (runoff, deep drainage and evaporation form the soil). Scheduling decisions could be based on the soil water status, crop status and/or atmospheric conditions, and also need to account for soil and irrigation system properties.

A range of tools are available to assist with irrigation scheduling – from direct measurement of soil water content to weather-based models for estimating crop water use and soil water status. For more information see information sheets titled "*Basics of Irrigation Scheduling*" and "*Irrigation Scheduling Toolbox*".

Irrigation system efficiency and uniformity

Engineering efficiency refers to the ratio of benefits derived from an irrigation system relative to what was put in. Efficiency is therefore an indicator of losses within a specified boundary in a system. High efficiency implies low water losses. In the context of irrigation system efficiency, water loss refers to water that was extracted from the water source but not delivered to the crop root zone. Some loss of water **cannot** be avoided and is an inherent characteristic of the irrigation system. For example, overhead sprinkler systems lose water through wind drift and evaporation of spray. Drip systems lose water through filter backwashing, and flood irrigation systems with earth canals lose water through seepage. Other minor losses may also occur. The ideal efficiency figures published in Table 1 reflect the generally acceptable level of losses which are inherent and unavoidable for each irrigation system. These efficiency figures are used to convert net irrigation requirements to gross irrigation requirements during the design process.

If a system is operating at a lower efficiency (typical industry values shown as minimum values under the efficiency column in Table 1), the water loss is excessive and can be prevented or avoided. Sources of excessive water loss include burst or leaking pipes, worn out rubber seals, nozzle wear and over-irrigation resulting in runoff or deep drainage.

Table 1. Acceptable performance benchmarks of irrigation systems

Irrigation systems		[1]Efficiency		Uniformity
		Typical values	Ideal/ acceptable values	
Overhead sprinkler	Dragline	70%	83%	CU > 80%
	Semi-permanent	70%	83%	CU > 80%
	Permanent/Fixed	75%	90%	CU > 80%
	Centre Pivots	80%	90%	CU > 85%
	Travelling Big Guns	65%	78%	CU > 80%
Drip	Surface Drip	90%	95%	slope < 2% => EU > 95%
	Sub Surface Drip	90%	95%	slope > 2% => EU > 90%
Surface/Flood	Furrow (earth canals)	60%	86%	DU_{lq} > 70%
	Furrow (lined canals)	70%	93%	DU_{lq} > 70%
	Furrow (piped supply)	80%	98%	DU_{lq} > 70%

[1]Effiency = Net to gross irrigation ratio.
CU = Coefficient of Uniformity, EU = Emission Uniformity, DU_{lq} = Low quarter distribution uniformity.

Source: Reinders *et al*. 2010. Standards and guidelines for improved efficiency of irrigation water use from dam wall release to root zone application. WRC report TT 466/10.

SABI Norms for the design of irrigation systems. Accessible from: http://www.sabi.co.za/design.html

Irrigation uniformity refers to how evenly water is applied across the field. Non-uniform irrigation implies that some parts of the field are receiving too little water while other parts may be receiving too much (Figure 2).

Irrigation can be very uniform and have a low efficiency – one can uniformly over-irrigate. However, irrigation cannot be non-uniform and efficient. Hence, uniformity is a good indicator of potential efficiency. Ideally irrigation must be both uniform and efficient. Poor uniformity can be caused by poor design or system hardware operation.

An irrigation system should be installed, operated and maintained according to specification. SABI accredited designers should be used to ensure that an irrigation system is designed according to acceptable norms and standards.

A basic understanding of the fundamental concepts in this information sheet is required for irrigation management. This knowledge will also prove useful when communicating with designers, installers, Extension Specialists or scientists about irrigation.

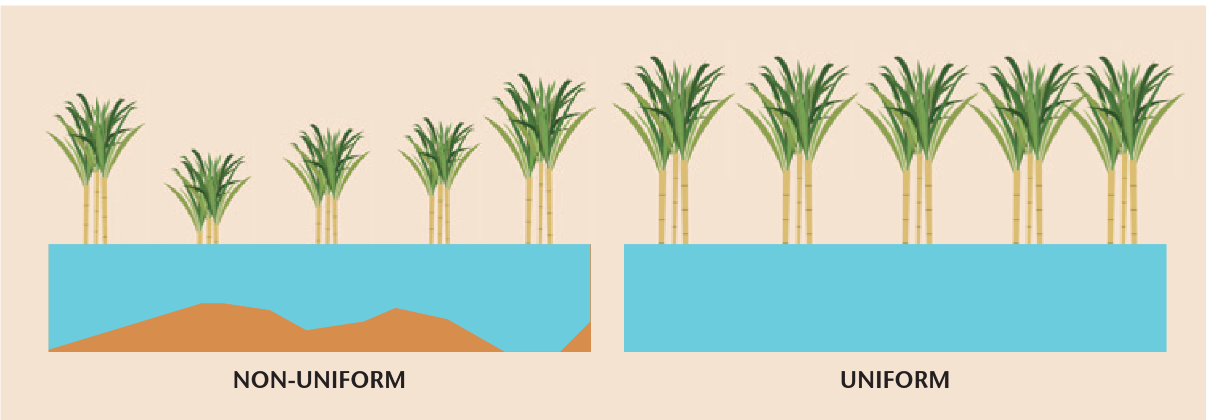


Figure 2. Illustration of uniform and non-uniform irrigation application

Compiled by Ashiel Jumman (Agricultural Engineer)
March 2016