# Improving irrigation water use efficiency

# Irrigation scheduling using a water balance

The principle of the water balance sheet approach is that the change in water content of the soil is represented by the difference between the water that has entered (by rainfall and irrigation) and the amount that has left (by drainage, run-off and evapotranspiration from the soil and crop).

That is, the daily change in soil water *content* = Inputs - Outputs. If inputs > outputs, then the soil becomes wetter; if outputs > inputs, then the soil becomes drier.

In irrigation, it is common to describe the soil water status in terms of a *soil water deficit* (SWD) rather than a soil water content. The SWD is defined as the difference between the present water content and the field capacity (FC) water content. If the soil is drier than field capacity, then the soil water deficit is positive.

Therefore, the daily change in soil water deficit = Outputs - Inputs

- If inputs > outputs, soil water deficit becomes less
- If outputs > inputs, soil water deficit becomes greater.

$SWD_i - SWD_{i-1} = ET_{i-1} - R_{i-1} - I_{i-1}$

By rearranging the above equation, we get

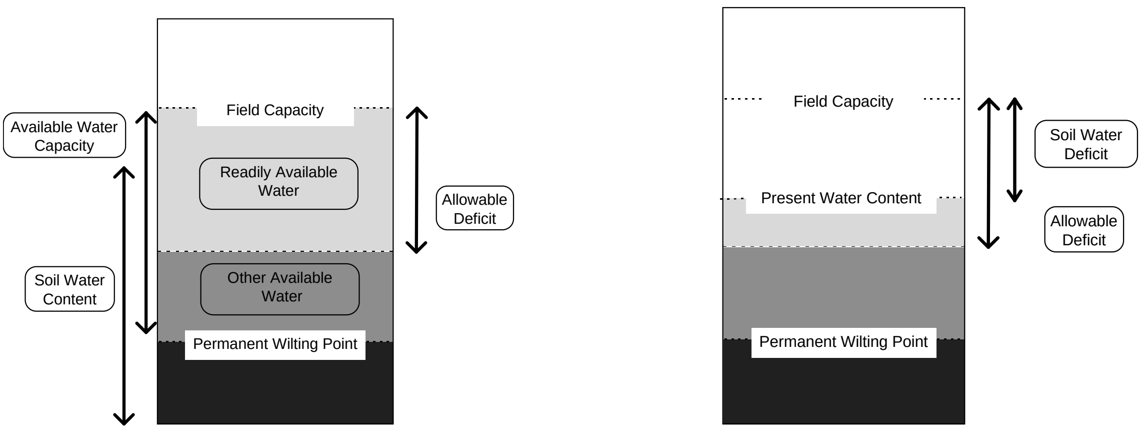
$SWD_i = SWD_{i-1} + ET_{i-1} - R_{i-1} - I_{i-1}$

where

| | |
|---|---|
| $SWD_i$ | soil water deficit at time i |
| $ET_i$ | crop water use at time i |
| $R_i$ | rainfall at time i |
| I | irrigation at time i |

We can measure, or estimate, the inputs and outputs, therefore we can model how the soil water content is changing from day to day.

**Figure 1 Soil water deficit**




Irrigation can be scheduled by defining an allowable soil water deficit at which irrigation should commence (e.g. limit of readily available water). Once the allowable deficit is reached an irrigation is due.

**Table 1 A simple soil water balance**

| $SWD_{i-1}$ | $+ ET_{i-1}$ | $- R_{i-1}$ | $- I_{i-1}$ | $= SWD_i$ |
|---|---|---|---|---|
| 0.0 | 2.0 | 0 | 0 | 2.0 |
| 2.0 | 2.5 | 0 | 0 | 4.5 |
| 4.5 | 3.0 | 3 | 0 | 4.5 |
| 4.5 | 3.0 | 0 | 0 | 7.5 |
| 7.5 | 3.0 | 0 | 0 | 10.5 |
| 10.5 | 3.5 | 0 | 0 | 14.0 |

## Inputs

We can measure rainfall and irrigation applications, however these are very localised and must be measured in situ.

*Rainfall*

Most farmers record rainfall on their farm on a daily basis. usually at one site, with a rain gauge placed conveniently near the farmhouse or office. However, because rainfall is highly variable over even very short distances, ideally a network of rain gauges should be located across the farm, and their readings taken on a daily basis.

*Irrigation*

The net irrigation amount applied is not so easy to determine, since unless a number of catch cans are placed in the field before each irrigation, the farmer must rely on the manufacturers data concerning water application rates (mm applied) and water distribution (uniformity). But doing an occasional catch can test can provide a useful indication of the difference between what was meant to be applied and what was actually applied. However, there are also many difficulties associated with interpreting data from catch cans; one option instead is to place a line of rain gauges across the field and check the amounts of water applied following the pass of the gun, and use this information to check whether the scheduled application depth has been ‘on average’ successfully applied.

Ensuring that the equipment is operating at the correct pressure at the gun will also help to ensure that the correct discharge and hence correct scheduled application depth is being applied; other effects (e.g. wind) will of course effect the actual depths of water applied.

## Outputs

*Crop evapotranspiration (ETc)*

If there is no drainage then the only output is crop evapotranspiration or ETc. This may be estimated in one of a number of ways;

1. Use climatological average rates of ETc for the region / time of year.
2. Use daily meteorological data and a 'Penman' type method to calculate ET. Need a well run, well sited met station measuring; temperature, humidity, wind speed, sunshine and / or solar radiation. An automatic weather station in UK costs <£2,000
3. A combination of the above. Daily weather data may be available from a local weather station, but only in retrospect. A common practice is to use ‘average’ rates of evapotranspiration, corrected weekly, or fortnightly, for actual readings from the local met station.

*Drainage*

Drainage of water below the root zone will only occur if irrigation or rainfall wets the soil profile beyond field capacity. A simplification used in many water balance scheduling methods is to assume any excess water, beyond field capacity is lost immediately, and the soil is returned to field capacity.

## Balance sheet

The balance sheet system lends itself well to forward planning because changes in SMD are directly proportional to water loss. So although it is not true to say that the actual need of the crop for water proceeds at a uniform rate, it is easy to estimate the earliest time at which the specified critical deficits will be reached. If planned deficits are exceeded (e.g. due to machinery failure/water resource restrictions) then the simple water balance sheet method will over-estimate water loss.

For day to day planning a balance sheet can be kept, like a bank balance (that is always in the red!). Therefore we need to know the daily inputs and outputs locally.

Most methods of estimating ET produce a value for a the potential ET from a reference crop. Actual ET from the crop in question will have to be estimated. The estimation should account for;

- the type of crop;
- the ground cover (some crops may not reach 100%, even at full cover), and;
- the degree of stress. If the crop is under stress it will be less than potential (although if irrigation is effective, there should be no stress!).

Details on how to produce an irrigation schedule using a simple water balance sheet approach are attached.

## *Computer water balance models*

Accurate calculation of actual ET is very complicated and depends upon;

- ETo
- crop type
- crop cover fraction
- frequency of wetting of crop / soil surface
- crop / soil condition (under stress or transpiring freely?)

A properly run water balance requires much repetitive calculation and is therefore ideally suited to a computer application.  Some are simple spreadsheets (e.g. Hess; 1993), others are specialised interactive programmes.

- When using the computer, more sophisticated models can be used to calculate actual ET from the weather, crop and soil information.
- Daily calculation is very quick so can be run for several fields.
- The rate of drainage can be related to the wetness of the soil
- Can use the computer model to extrapolate forward, based on certain assumptions about the weather, and forecast the time of the next irrigation.

## *Limitations of water balance methods*

- Accuracy of input data (Garbage In Garbage Out).  Accuracy and spatial variation of rainfall data and irrigation amount.  Rainfall is very variable over short distances. Irrigation amounts are rarely measured accurately.

- Cumulative errors.  As each day's deficit is calculated from the previous day's errors are compounded.  e.g. if ETo is -0.5 mm out every day, then in 10 days this is equal to 5 mm. However, model is reset every time soil comes back to field capacity.
- The balance sheet method is 'areal averaging' and cannot say anything about point to point measurements, in contrast to in-situ soil moisture measurement such as the tensiometer or neutron probe.

## *Combined water balance and in-field monitoring*

In-situ measurements of soil water content or potential are time consuming, subject to spatial variability and difficult to use to forecast irrigation need, whilst water balance methods are prone to cumulative errors.

A good compromise therefore combines the two, using a water balance sheet approach for the day-to-day scheduling with occasional 'spot checks' using in-situ soil measurements (e.g. neutron probe or tensiometer).