10 Management aspects

J.G. Kroes, J.C. van Dam

10.1 Introduction

A dynamic model like SWAP can be applied in various ways to analyse water management aspects. The applications in this field may range from a simple static impression of a seasonal water balance to detailed assistance in timing aspects of fertilizer strategies. Due to the large range of its applications this chapter does not pretend to give a complete picture of all management aspects, but focusses on the most important items. Examples are given for: irrigation, drainage, land use and surface water management.

10.2 Sprinkling and surface irrigation

Water balance simulation models are applied for irrigation scheduling in order to develop optimal irrigation schedules by evaluating alternative water application strategies. A common objective at irrigation scheduling is to maximize net return. Other objectives may be: minimize irrigation costs, maximize yield, optimally distribute a limited water supply, minimize groundwater and surface water pollution, or optimize the production from a limited irrigation system capacity. In semi-arid and arid zones irrigation may cause salinity problems. If natural drainage for leaching is not present, artificial drainage has to be installed to create favourable moisture and salinity conditions in the root zone. SWAP can be used to support the design of a combined irrigation and drainage system, including sub-irrigation.

The appropriate management objective depends on the available water amounts and the irrigation costs. In many cases it is optimal to produce near maximum yields on the entire area that can be irrigated. Then the prime objective is to prevent crop water stress throughout the growing season. In case water supplies do not allow irrigation for maximum yield, or irrigation costs are that high, that the economic optimum level of irrigation is below the yield maximizing level, deficit irrigation must be practised. The objective of irrigation management under these conditions is to maximize the economic returns to water and generally three decision criteria are involved:

- how much area to irrigate;
- which crops to plant;
- how to distribute the available supply over the irrigable area during the season.

If land amount is limiting and water is available but expensive, net returns to land are to be optimized: maximum economic efficiency occurs when the cost of an additional unit of water just equals the value of the resulting crop yield increment.

10.2.1 Irrigation scheduling options

In SWAP irrigations may be prescribed at fixed times or scheduled according to a number of criteria. Also a combination of irrigation prescription and scheduling is possible. The scheduling criteria define the time when irrigation should take place, as well as the irrigation depth. A specified combination of timing and depth criteria is valid from a user defined date in the cropping season until the end of crop growth. Both timing and depth criteria may be dynamic i.e. be defined as a function of crop development stage. The reduced growth rate and final yield due to soil moisture stress will depend on the time of occurrence of the stress during the growth cycle. If the stress period occurs during rapid plant growth and high water demands, or when reproductive processes are critical, the effect of stress will be larger than during stress periods of similar length when growth and development are slow, such as near maturity.

The irrigation scheduling criteria applied in SWAP are similar to the criteria in CROPWAT (Smith, 1992), IRSIS (Raes et al., 1988), and the Hydra Decision Support System for Irrigation Water Management (Jacucci et al., 1994).

10.2.2 Timing criteria

Five different timing criteria can be selected to generate an irrigation schedule:

10.2.2.1 Allowable daily stress

Irrigation is applied whenever due to dryness conditions the actual transpiration rate T_a drops below a predetermined fraction f_1 (-) of the potential transpiration rate Tp:

$$T_{\mathrm{a}} \leq f_1\, T_{\mathrm{p}} \tag{10.1}$$

This option is relevant for sub-optimal (deficit) irrigation when the water supply is limited.

10.2.2.2 Allowable depletion of readily available water in the root zone

Irrigation is applied whenever the water depletion in the root zone is larger than a fraction f_2 (-) of the readily available water amount:

$$\left(U_{\mathrm{field}} - U_{\mathrm{a}}\right) \geq f_2\left(U_{\mathrm{field}} - U_{\mathrm{h3}}\right) \tag{10.2}$$

where U_{a} (cm) is the actual water storage in the root zone, U_{field} (cm) is the root zone water storage at h = -100 cm (field capacity), and U_{h3} (cm) is the root zone water storage at $h = h_3$, where root water extraction starts being reduced due to drought stress (Figure 5).
U_{a} is calculated by integrating numerically the water content in the rooting layer. This option is useful for optimal scheduling where irrigation is always secured before conditions of soil moisture stress occur. For deficit irrigation purposes, stress can be allowed by specifying $f_2 > 1$.

10.2.2.3 Allowable depletion of totally available water in the root zone

Irrigation is applied whenever the depletion is larger than a fraction f_3 (-) of the total available water amount between field capacity and permanent wilting point:

$$\left(U_{\mathrm{field}} - U_{\mathrm{a}}\right) \geq f_3\left(U_{\mathrm{field}} - U_{\mathrm{h4}}\right) \tag{10.3}$$

where U_{h4} is the root zone water storage at $h = h_4$, the pressure head at which root water extraction is reduced to zero (Figure 5).

10.2.2.4 Allowable depletion amount of water in the root zone

Irrigation is applied whenever a predetermined water amount, ΔUmax (cm), is extracted below field capacity:

$$U_{\mathrm{a}} \leq U_{\mathrm{field}} - \Delta U_{\max} \tag{10.4}$$

This option is useful in case of high frequency irrigation systems (drip).

10.2.2.5 Critical pressure head or moisture content at sensor depth

Irrigation is applied whenever moisture content or pressure head at a certain depth in the root zone drops below a prescribed threshold value θ_{min} (cm^3 cm^{-3}) or h_{min} (cm):

$$\theta_{\mathrm{sensor}} \leq \theta_{\min} \qquad \text{or} \qquad h_{\mathrm{sensor}} \leq h_{\min} \tag{10.5}$$

This option may be used to verify field experiments or to simulate irrigation with automated systems.

10.2.3 Application depth criteria

Two irrigation depth criteria can be selected:

10.2.3.1 Back to Field Capacity (+/- specified amount)

The soil water content in the root zone is brought back to field capacity. An additional irrigation amount can be defined to leach salts, while the user may define a smaller irrigation amount when rainfall is expected. This option is useful in case of sprinkler and micro irrigation systems, which allow variation of irrigation application depth.

10.2.3.2 Fixed irrigation depth

A specified amount of water is applied. This option applies to most gravity systems, which allow little variation in irrigation application depth.

10.3 Design of field drainage

Drainage design can be evaluated using the equations of Hooghoudt and Ernst (paragraph 4.2.2). Using these formulae one may analyse the impact of various physical parameters (soil, crop, climate) on drain spacing and drain depth. More examples are extensively elaborated by Ritzema (1994).
Combining options for irrigation (paragraph 10.2) and salinity (chapter 8) one may analyse the relation between irrigation, drainage and field scale soil salinity.

This may be further elaborated towards the impact on crop production using the Wofost-options described in paagraph 7.3

10.4 Land use

The impact of land use alternatives can be analysed in may ways. Some examples are:
- introduce different crops and crop-rotations;
- change phenological parameters, such as time of emergence and/or harvest;
- vary temperature sums that determine crop development;

This can be carried out by changes on imput parameters (paragraph 11.1) for simple or detailed crop module (for details see respectively paragraph 7.2 or 7.3).

10.5 Surface water management

The interaction between groundwater and surface water system may be analysed using the various options described in chapter 4. Examples of management strategies are:
- Change variations in the dynamics of surface water levels and analyse its impact on groundwater, and agricultural management or growth of natural vegetations;
- Change the inlet or outlet of a region and its corresponding surface water levels;
- Analyse impacts of weather extremes (dry or wet);
- Analyse a change in the variation of weather dynamics on surface and groundwater levels;
- Introduce shallow systems (trenches, ditches) and analyse its impact on the soil water balance;
- Simulate effects of poor maintenance of surface waters (tube drains or ditches) by adjusting drainage resistances;
- reconstruct drainage systems

For polder systems or other areas where a uniform waterlevel occurs in a larger area this can be carried out with the extended drainage option (paragraph 4.2.5). In other areas special care should be taken about the influence of the lower boundary condition on groundwater and surface water levels. If this influence is very large then it is recommended to use a regional groundwater model.