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CHARTS WITH INDICATIVE IRRIGATION INTERVALS FOR VARIOUS WEATHER CONDITIONS

by

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Charts with indicative irrigation intervals for various weather conditions

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Abstract
The unreliability of rainfall, and the absence of guidelines at a short time-step often complicate decision-making during the irrigation season. The paper presents a procedure for developing irrigation charts to help farmers in their day-to-day decisions. The chart guides the user in the adjustment of the irrigation interval to the actual weather conditions throughout the growing season. In case of water shortage during a particular period, additional data informs the user on the sensitivity of the crop to water stress. By considering the climate of the region, crop and soil characteristics, the irrigation method and local irrigation practices, the charts are developed. It is believed that the simplicity of the chart makes it a useful tool for a better utilisation of the precious irrigation water.

Key words: irrigation, management, scheduling

1. Introduction
A range of irrigation scheduling methods have been developed to assist farmers and irrigators to apply water more efficiently taking into account crop evaporation and rainfall. However at small farmers' level, such methods can not be applied in a practical manner as they require sophisticated monitoring equipment and data processing. Indicative irrigation calendars have proved useful for small holder farmers using mean climatic data and standardized crop and soil data. Fixed irrigation intervals and fixed application depths are recommended to the farmers with or without some empirical adjustments to actual weather conditions. Fixed calendars however are less reliable in conditions of varying rainfall. Guidelines at a short time-step often complicate decision-making during the irrigation season. The corresponding irrigation applications are often characterised by periods of over- and under-irrigation. Excess watering may cause water logging, excessive vegetative growth and loss of valuable nutrients out of the root zone. Withholding irrigation, especially during crop sensitive periods, will result in limited growth and reduction in crop yield.

This paper outlines a methodology to develop irrigation calendars that give farmers simple guidelines on how to adjust their irrigation during the growing season (i) to the actual weather condition and (ii) when shortage in the supply of irrigation water occurs

(Raes et al., 2000; De Nys et al., 2001). The developed irrigation guidelines are presented in irrigation charts and with the help of an extension service transferred to farmers. Each chart presents guidelines for the irrigation scheduling of a specific crop, for a particular region, soil type, growing season and irrigation method. In order that farmers adopt the guidelines, the calendar should be easy to consult.

2. Data Collection

For the development of irrigation charts a good knowledge of the regional climatic conditions, physical soil parameters, crop characteristics, and the ongoing irrigation practices is required.

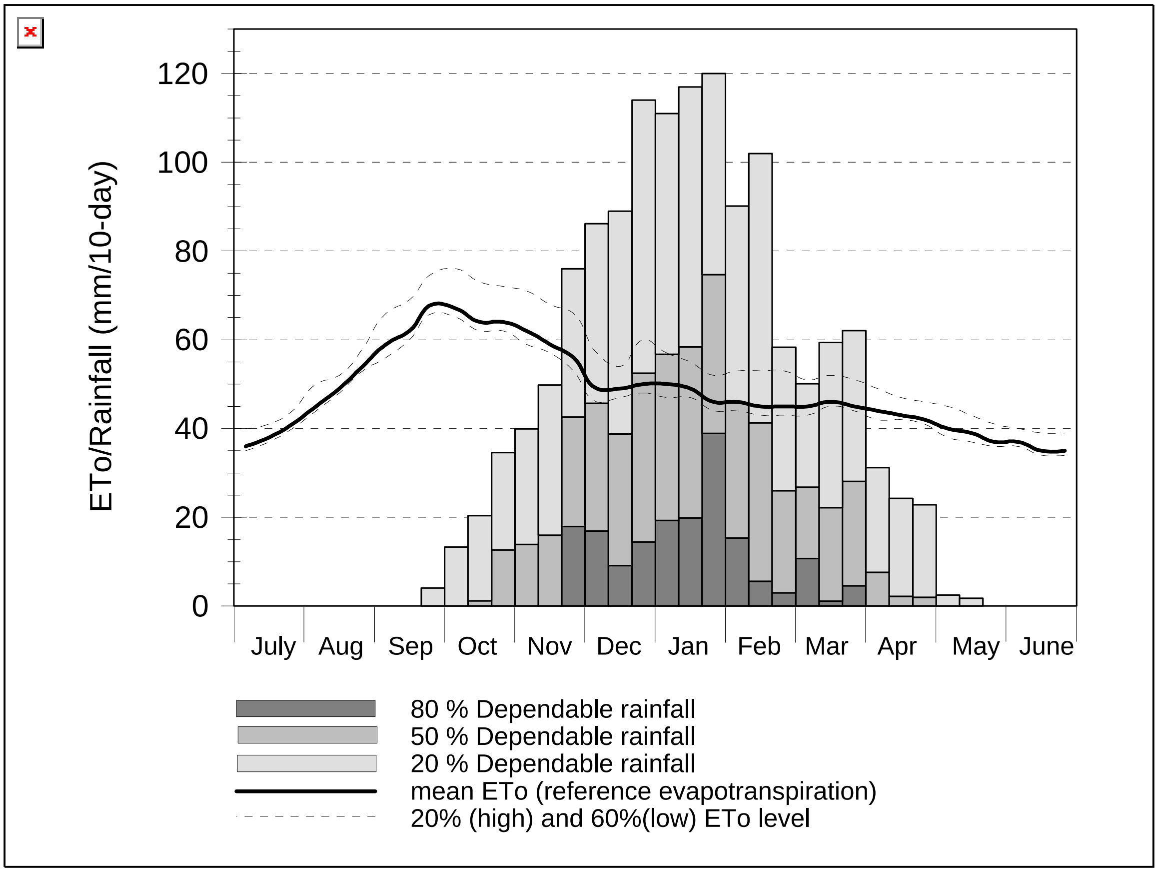


Figure 1.
10-day Rainfall and ETo levels
with various probability levels (%) of exceedance for Harare (Zimbabwe).

Since the objective of the irrigation chart is to give farmers guidelines for the adjustment of their irrigation calendars to the actual weather conditions, the development of the irrigation calendars requires information on rainfall and evapotranspiration levels that can be expected with various probabilities. The probabilities can be derived statistically from 10-day rainfall and ETo records from the last 15 to 25 years by means of a frequency analysis (Raes et al., 1996). Reference crop evapotranspiration (ETo), which is an index for the evaporating demand of the atmosphere, can be estimated from climatic data by means of the FAO-Penman Monteith equation or from pan evaporation (Allen et al., 1998). As an example, various levels for ETo and Rainfall for Harare (Zimbabwe) are plotted in Figure 1. By combining various probability levels of ETo and rainfall, four weather conditions are distinguished (Tab. 1) for which an irrigation advice will be formulated.

Table 1. The four distinguished weather conditions in irrigation charts

Weather condition	Probability level of exceedance	
	ETo	Rain
Hot and dry	20 %	100 % (No rain)
Dry	40 %	80 %
Normal	50 %	50 %
Wet	60 %	20 %

Although indicative values for most crop parameters are available in literature, the length of the growing period and the typical planting/sowing data of the considered crop variety should be collected at farmers' fields. Typical crop coefficients, procedures for adjusting the crop coefficients to climatic conditions and for calculating crop evapotranspiration are presented by Allen et al. (1998). The crop coefficient (Kc) integrates the effects of characteristics that distinguish field crops from the reference surface. Crop evapotranspiration (ETc) is calculated by multiplying ETo by Kc.

The Total Available soil Water (TAW) is an important soil physical characteristic that needs to be determined when formulating irrigation guidelines. TAW refers to the total amount of water available in the root zone that can be utilized by the crop. The soil water content at field capacity and permanent wilting point are respectively the upper and lower limits of TAW. Field capacity is the quantity of water that a well-drained soil would hold against the gravitational forces. Permanent wilting point is the soil water content at which plants stop extracting water and will permanently wilt. If measured values for field capacity and wilting point are missing they can be estimated from various soil properties (Rawls et al., 1982; Saxton et al., 1986; Ritchie et al., 1999). The Readily Available soil Water (RAW) is the amount of water that crops can extract from the root zone without experiencing any water stress (RAW). It is a fraction (p) of TAW. Allen et al. (1998) present indicative values for the soil water depletion fraction for no stress (p) and ranges for effective rooting depth for common crops.

For the design of the irrigation calendars, the irrigation application depth is often considered as fixed. Fixed application depths in combination with a variable irrigation interval results in an efficient use of the irrigation water. The selected value for the fixed net application depth depends on the soil type, crop type, irrigation method and equipment and local irrigation practices at farmers' fields. The gross application depth, the irrigation depth applied by the farmers, will be larger and has to be determined by considering the irrigation efficiency at field level.

3. Soil water balance

Irrigation calendars are developed by means of a soil water balance technique. It consists in first calculating the net irrigation requirement, which is obtained by subtracting from the crop water requirement (ETc) the expected gains of water through rainfall. In case of a shallow ground water table the water contribution by capillary rise should be considered as well.

Given the fixed net irrigation application depth, the irrigation interval can subsequently be derived by plotting the root zone depletion along the time axis (Fig. 2). At sowing/planting the soil water content is often at field capacity (root zone depletion is zero) as a result of a pre-irrigation. The rate of root zone depletion at a particular moment in the season is given by the calculated net irrigation requirement for that period. Each time irrigation water is applied, the root zone depletion decreases with the applied net irrigation depth. Generally the irrigation will be frequent during peak periods when the crop water demand is high and rainfall small. On the other hand, the applications are less frequent at the end and beginning of the season when ETc is small or rainfall frequent.

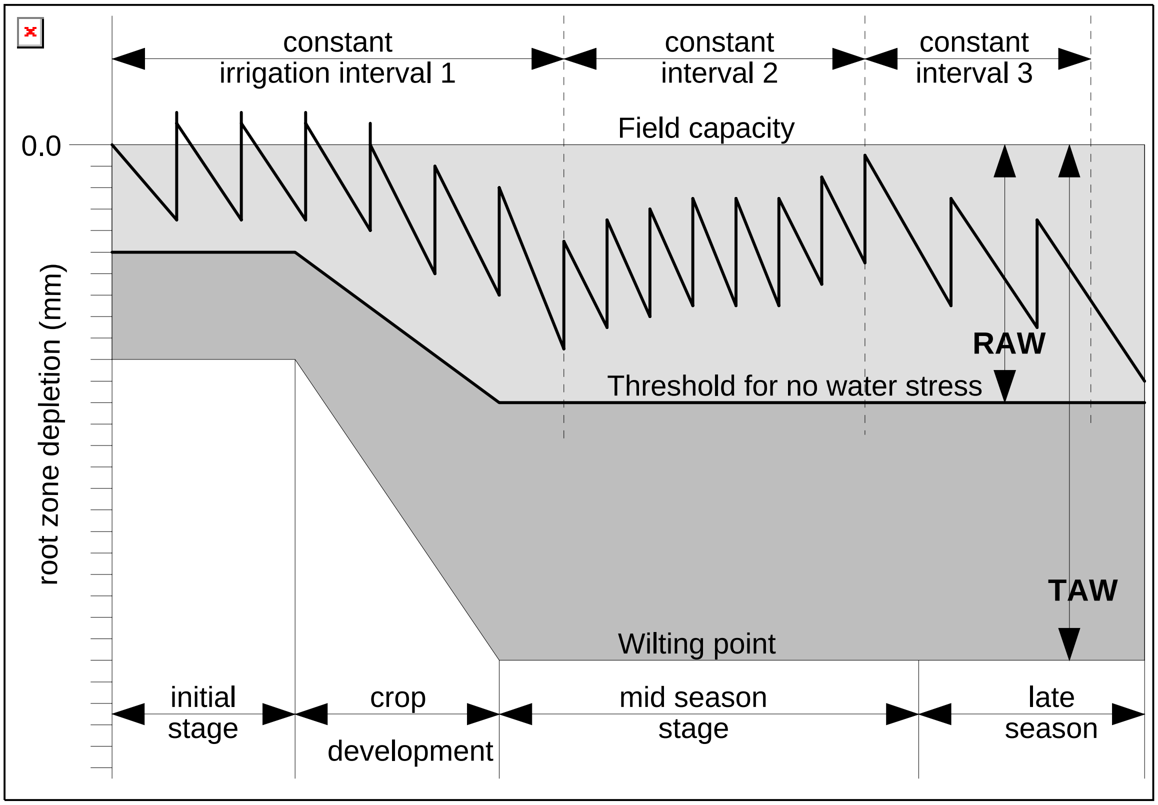


Figure 2
Root zone depletion (broken line)
for a schedule with a fixed irrigation application depth

To avoid crop water stress, the root zone depletion should not exceed the threshold value for no stress (lower limit). If so, the depletion will be larger than RAW and the crop will experience water stress. The resulting yield decrease depends on the severity of the stress and the sensitivity of the crop at the particular growth stage. On the other hand, to avoid water losses, the soil water content in the root zone after an irrigation event should not exceed field capacity (upper limit). Any excess of irrigation water will be lost by deep percolation. By altering the irrigation interval during the season, one is able to keep the root zone depletion between the lower and upper limit (Fig. 2).

With the described technique, irrigation intervals can be determined for the four weather conditions (Tab. 1). With the help of soil water balance models (Raes et al., 1988; Smith, 1989; Raes, 2002), alternative solutions can be quickly developed and evaluated.

4. Irrigation charts

The designed irrigation schedules for the four weather conditions are presented in a coloured Irrigation Chart (Figure 3a and b). The chart presents guidelines for adjusting the irrigation interval to the actual weather conditions for a specific crop, particular region, soil type, planting date and irrigation method.

4.1 Adjustment of Irrigation interval

Indicative values for irrigation intervals for the four considered weather conditions (Tab. 1) in a particular period of the growing season are presented on the front of the Chart (Fig. 3a). As a reference, 10-day rainfall amounts expected during dry, normal and wet weather conditions are plotted on the back of the chart (Fig. 3b).

Indicative intervals under hot and dry weather conditions are given in line 1, and for dry weather conditions with insignificant rainfall in line 2 (Fig. 3a). When rainfall of one or successive days is significant, the interval between irrigations can be stretched. Expected mean intervals for rainy periods are given in line 3 (normal weather) or line 4 (wet weather). The adjustment of the irrigation interval during periods of rainfall, should consider the amount of rainfall that is recorded:

- If rainfall is important (equal or higher than the irrigation application depth) then the rainfall will replace irrigation. Guidelines for the irrigation interval after rainfall are given in line 1 (hot weather) or line 2 (normal dry weather);
- If rainfall is smaller than the irrigation application depth, then the irrigation can be delayed with a number of days calculated by multiplying the advised interval (in line 1 or line 2) with a delay factor. This factor is equal to the rainfall amount divided by the net irrigation application depth and hence smaller than 1.

> **Example**
> Advised irrigation application depth is 20 mm and a rainfall shower of 10 mm occurs:
> → delay factor is 10/20 = 0.5
> If the advised irrigation interval for weather conditions after rainfall (line 1 or 2) is 4 days:
> → the interval of 4 days can be INCREASED with (0.5) x 4 days = 2 days.

It is a good practice to compare the stretched irrigation interval during rainy periods with the guidelines in line 3 or 4. If the stretched interval is on average much smaller than the advised interval, it is likely that one is over-irrigating. If the interval is larger, one is likely to under-irrigate and the crop might experience some water stress.

Irrigation guidelines for:

Potatoes

Soil type: clay (Harare 5E2)
Irrigation application gross depth: 25 mm

Irrigation interval given in days

Month		December			January			February			March		
Decade (10 days)		1	2	3	1	2	3	1	2	3	1	2	3
Actual weather condition	Hot + dry	4 days					3 days			4 days			
	Dry	7 days								4 days		7 days	
	Normal	20 days								7 days			
	Humid	20 days											
Growing stage		Germination	Vegetative development					Flowering		Yield formation + ripening			
Sensitivity to water-stress		very (a)	moderate sensitive (b)				sensitive (c)	very sensitive (a)		sensitive (c)			not (d)

(a) The crop is extremely sensitive to water-stress during establishment. Also during flowering water shortage should be avoided.
(b) During the early vegetative stage, the crop is moderate sensitive to water-stress and furthermore, root development is encouraged by a limited water supply.
(c) When the crop reaches its maximum crop development, the highest values of transpiration can be observed. This makes the crop very sensitive to water-stress. Also during yield formation sufficient water should be applied to avoid a decrease in yield.
(d) During ripening, less water is required.
Mind! Do not irrigate at the end of the day, so that leaves are dry when night falls. If they are wet during the night, Late Blight can occur!

Irrigation conditions

Growing season

- planting: begin December
- harvesting: end March

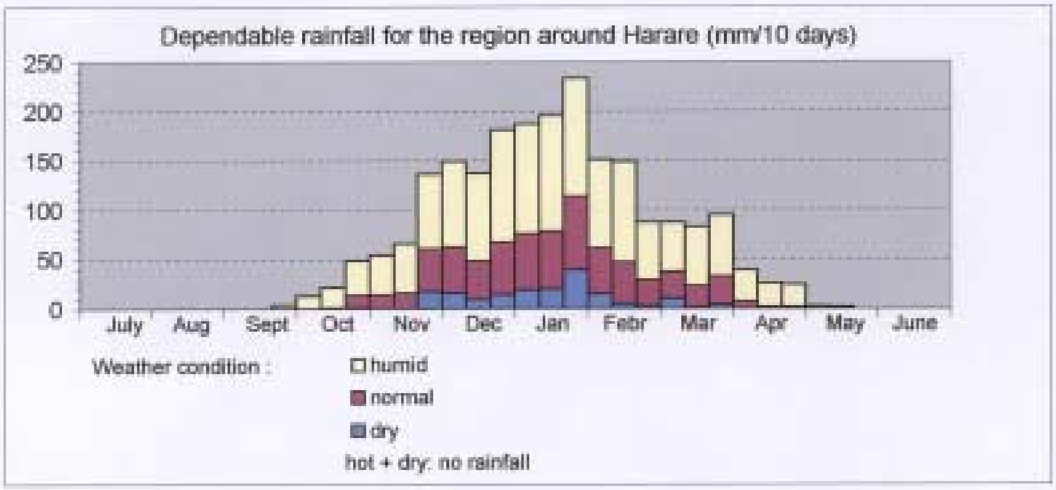
Region II

Sprinkler irrigation

75% field application efficiency

Figure 3a
Example of an Irrigation Chart (front side)
for potatoes cultivated in the region of Harare on a clay soil,
presenting indicative irrigation intervals for four weather conditions (Holvoet, 2002)

Determination of the weather condition



Crop evapotranspiration (mm/10 days)

Month	December			January			February			March		
Decade (10 days)	1	2	3	1	2	3	1	2	3	1	2	3
Potatoes (wintercrop)	29	29	32	39	47	53	54	52	47	40	39	35
Growing stage	Germi-nation	Vegetative development					Flowering		Yield formation + ripening			

Developed by:

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Figure 3b
Example of an Irrigation Chart (back side)
for potatoes cultivated in the region of Harare on a clay soil,
presenting indicative irrigation intervals for four weather conditions (Holvoet, 2002)

4.2 Water shortage

Information about crop sensitivity to water stress at the various growth stages is presented at the bottom of the Table of the irrigation interval on the front of the chart (Fig. 3a). In case of water shortage, these references are useful to further adjust irrigation scheduling while still maximising production. By delaying irrigation during periods of low to moderate water stress, irrigation water can be saved. A slight to moderate increase of the interval will not strongly affect crop yield. Delaying irrigation applications during periods when the crop is sensitive to very sensitive to water stress, should be avoided.

4.3 Adjusting the irrigation dose

For the design of the alternative irrigation intervals, a fixed application depth was selected in function of local practices, soil and crop parameters and irrigation method. The chart still provides valid guidelines for irrigation planning when farmers prefer to adjust both the application depth and interval of their irrigation, as long as the link between the application and interval is respected. If a farmer increases the application depth with 20 percent, the farmer also has to increase the proposed irrigation interval with 20 percent.

Variations of the irrigation application depth should remain moderate. Indeed, if the irrigation application becomes too small, the water distribution on the field will not be uniform. On the other hand, if the application depth is much larger than the advised application depth, large water volumes might drain out of the rooting zone and lost by deep percolation. This will not only spoil precious irrigation water, but also flush out valuable nutrients of the root zone.

4.4 Crop evapotranspiration

Crop evapotranspiration expected under normal meteorological conditions for each decade of the growing period are presented at the backside of the irrigation chart (Fig. 3b). With the help of this table and information on the actual rainfall, enterprising managers and farmers with a good knowledge of the characteristics of their irrigation system can develop their own irrigation calendar.

5. Conclusions

Irrigation systems and schedules are mostly designed to cover irrigation requirements during the peak period, when crop evapotranspiration is high and rainfall is scarce. Outside this peak period, irrigation scheduling needs to be adapted to the prevailing weather conditions. The unreliability of rainfall, and the absence of guidelines at a short time-step often complicate decision making during these irregular periods.

To provide farmers with some guidelines, a procedure was presented to develop 'Irrigation Charts' which can be distributed to farmers with the help of the extension service. The charts give farmers indicative values for irrigation intervals for four different weather conditions. Its simplicity makes it a useful tool to help decision-making for all actors involved in irrigation management.

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