"ZIMsched": An Irrigation Management and Yield Forecasting Tool

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Abstract

A major constraint to farmer acceptance of irrigation management tools is that many farmers find that most tools lack a sense of familiarity and/or are relatively complex, time-consuming and confusing to operate. In order to address these issues a spreadsheet-based irrigation management tool, "*ZIMsched*" has been developed with farmer participation. Because the tool is spreadsheet based many farmers find it familiar to use and are quick to relate to it. In this paper *ZIMsched* is presented and the internationally proven concepts and algorithms which are used in *ZIMsched* to account for:

- runoff generation, deep drainage and rainfall effectiveness,
- the effects of temperature on the rate of canopy and root development, and
- yield estimates that are sensitive to the effects of both under and over-irrigation (and excessive rain), soils and climate,

are described. *ZIMsched* is proving popular with both estates and individual growers in Zimbabwe.

Introduction

Many water-budgeting tools for irrigation management have been developed, however, few of these are seeing widespread use amongst growers as effective management aids. Explanations for this lack of effectiveness include:

- water budgeting methodologies that are based on hand calculations can be confusing, excessively time-consuming, error prone and often require that the soil-plant-atmosphere continuum be over-simplified in order to facilitate easy calculations;
- computer simulation models whilst having great potential for facilitating more efficient and accurate water budgeting are often unfamiliar and confusing, especially when it comes to configuring them for a particular situation or "resetting/re-initialising" them if simulations do not match field observations at a particular time.

Even if irrigation scheduling consultants operate computer simulation models and/or other tools and pass information on to farmers, this is not always ideal. Many consultants begin to lose touch with the realities on the ground as they are located at some distance from farms.

There is no doubt that water budgeting tools, when used correctly, can facilitate significant improvements in irrigation water management. A major challenge is to match accurate water budgeting with ease of use from a farmer's perspective. With this in mind "*ZIMsched*", a spreadsheet-based water management and yield forecasting tool has been developed. Spreadsheets were selected as the basis for developing *ZIMsched* because they are familiar to many people and have very powerful in-built functionality. In this paper *ZIMsched* is presented and the concepts and algorithms which are used in *ZIMsched* to account for the major components of the water budget and the crop yield estimates, are described.

Methodology

Complex mechanistic water budgeting and crop growth algorithms, whilst theoretically attractive, are often of limited value in many practical applications because the data, information and operator understanding they require are seldom available. Simpler and more robust algorithms have therefore been reviewed and incorporated into *ZIMsched*. Many of these algorithms are similar to those that have been used in the irrigation module of the *ACRU* agrohydrological simulation model (Lecler and Schulze, 1995).

Evaporation

In *ZIMsched*, evaporation from the cropped surface (evapotranspiration) is dependent on climatic conditions, soil water status, crop canopy status and rooting characteristics.

Crop coefficient

The crop coefficient is used to relate evaporation from the cropped surface to atmospheric evaporative demand (AED). In *ZIMsched*, the crop coefficient is related to thermal time in order to account for variations in the rate of canopy development that are associated with different planting/ratooning times (early, mid, late season), and seasonal temperature variations. The relationship between crop coefficients and thermal time was derived by Hughes (1989) using lysimeter data collected in Pongola and reported by Thompson (1986). It is given in Equation 1.

$$K_c = 0.297 + (1.32x10^{-6}xGD_a^{\,2}) - (6.83x10^{-10}xGD_a^{\,3}) \quad \text{Eq. 1}$$

where K_c = sugarcane crop coefficient (*ZIMsched* default value)

GD_a = accumulated thermal time since planting

Thermal time = $((T_{max}+T_{min})/2) - 12$ (E C)

T_{max} = daily maximum temperature (E C)

T_{min} = daily minimum temperature (E C)

Limits $K_c \leq$ 0.90 for a plant crop

$\leq$ 0.85 for ratoon crops

K_c = 0.90 or 0.85 (plant and ratoon) for $GD_a > 1300$ (to prevent -ve values)

The limits for K_c used by Hughes (1989) have been adjusted to those given above in order to suit local conditions in the south east lowveld of Zimbabwe. In the lowveld of Zimbabwe a $K_c \leq$ 0.85 for a full canopy crop is recommended based on the analysis of irrigation trial data from the Zimbabwe Sugar Association Experiment Station (ZSAES). Data from trials where full canopy sugarcane was irrigated using various fractions of evaporation from a class A-pan to determine irrigation intervals (so-called "pan factor" trials) are shown in Figure 1. There was little benefit in irrigating full canopy sugarcane using a K_c greater than 0.85, an observation also supported by Nyati (1996). Data from these trials also serve as an indirect calibration for evaporation losses from sugarcane in relation to the evaporation measured from an A-pan. The higher value of K_c equal to 0.90 for the plant crop, is based on observations reported on by Thompson (1986) and also Hodnett, *et al*. (1991) which show that the plant crop often uses more water than subsequent ratoons.

Atmospheric Evaporative Demand (AED)

The simple option available in *ZIMsched* is to use the evaporation measured using a class A-pan to represent AED. In Zimbabwe, most of the research involving sugarcane crop water use has been undertaken using the evaporation from A-pans as the reference evaporation (cf. Figure 1 and Nyati, 1996). Nevertheless the correlation between the evaporation from an A-pan and the evaporation from a cropped surface can be markedly different in summer and winter and also under advective conditions or when there are wide variations in wind and humidity (Allen *et al*., 1998). The use of a more representative reference evaporation than the A-pan, such as that defined by the Food and Agricultural Organisation, FAO (Allen *et al*., 1998) which is based on the Penman Monteith equation, may, therefore, result in gains in water use efficiency. For this reason, relationships between:

- the FAO Penman Monteith reference evaporation,
- a sugarcane version of the Penman Monteith equation (McGlinchey and Inman-Bamber, 1996)
- evaporation from a class A-pan, and
- evaporation from a relatively simple atmometer device (Asbell, 1999) that may better represent a plant,

are being investigated for possible future incorporation into *ZIMsched*.

Rooting Characteristics

In *ZIMsched*, the root zone which delimits the volume of soil from which water is available to the crop is dynamic in order to account for root growth. The depth of the zone from which water uptake can occur, R_z, is calculated by assuming a linear relationship to crop coefficients (Jensen, Burman and Allen,1990) which are, in turn, related to thermal time, *viz*.

$R_z = R_{fac} \cdot TAM$ Eq 2.

where R_{fac} = 0.4 for $K_c \leq 0.3$

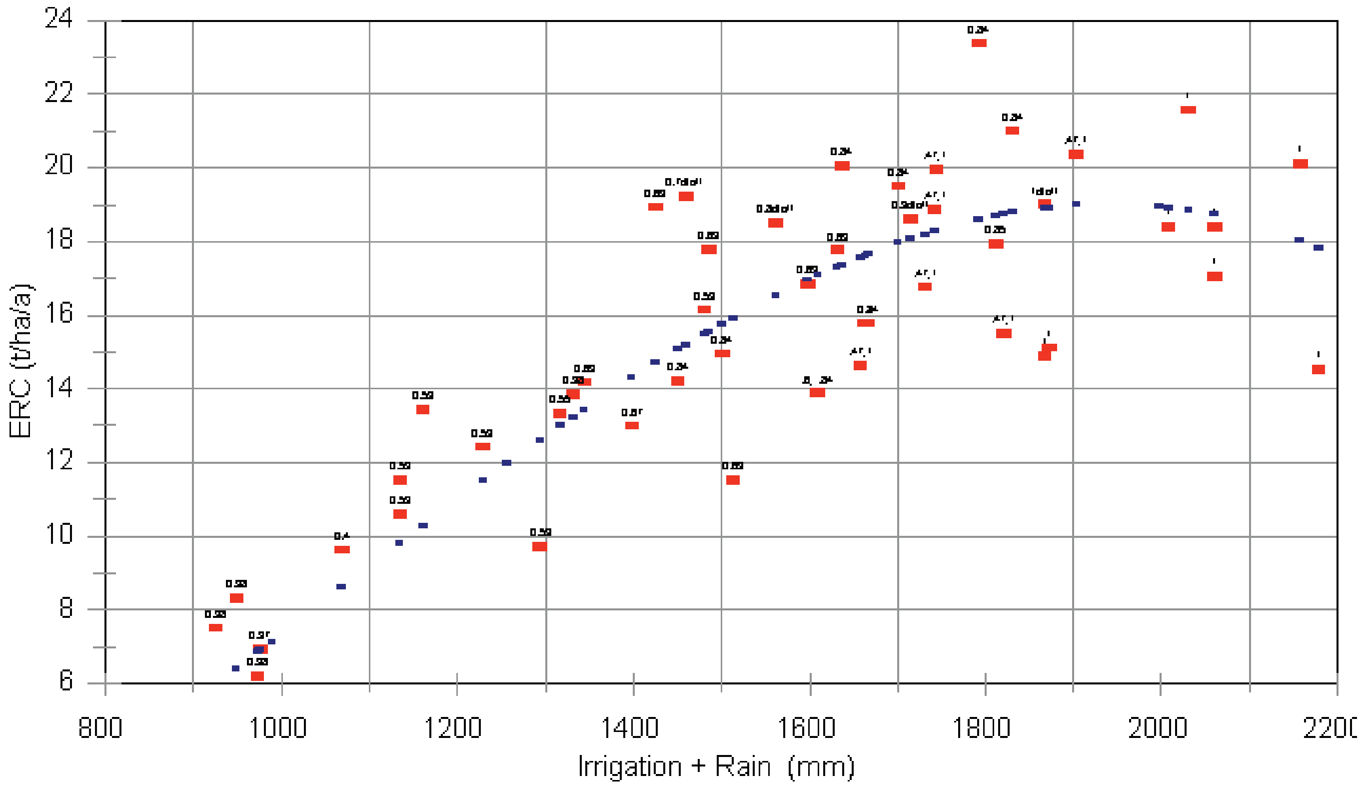

Figure 1. Estimated Recoverable Crystal (ERC) vs total water (irrigation + rain) for various crop coefficients or 'pan factors'. The data labels refer to various crop coefficients used to determine irrigation intervals for full canopy sugarcane.

$= (0.6/0.55).(K_c - 0.3) + 0.4$ for $0.85 > K_c > 0.3$

$= 1$ for $K_c > 0.85$

Evaporation Under Conditions of Soil Water Stress

Evaporation from the crop is reduced below potential if soils are too dry relative to AED according to a relationship derived by Slabbers (1980). Slabbers (1980) showed that the soil water content at which actual ET is less than potential ET is dependent on AED, *viz*. if it is very hot, water stress will start to occur at relatively high soil water contents, whereas if it is cool and humid, water stressing will only start to occur at relatively lower soil water contents. Evaporation is also reduced below potential if soils are above field capacity due to poor aeration. This is accounted for in *ZIMsched* using an equation from the *ACRU* model (Schulze, 1995) that follows work reported by Dijkhuis and Berliner (1988). The interrelationships used in *ZIMsched* between soil water content and the ratio of actual to potential evapotranspiration ($ET_{actual} : ET_{potential}$) are illustrated diagrammatically in Figure 2.

Surface Runoff

In *ZIMsched*, "surface runoff" is defined as the water which is generated on or near the surface of a field from a rainfall event. This water does not contribute to the soil water status and is, therefore, important for estimating rainfall effectiveness. Surface runoff is estimated using the Soil Conservation Service (SCS) (USDA,1985) stormflow equation as modified by Schulze (1995) and used in the *ACRU* agrohydrological simulation model. The modified equation is given below as Equation 2.

$$Q = (P_g - cS)^2/(P_g + S(1-c)) \qquad \text{Eq. 3}$$

where Q = surface runoff depth (mm)

P_g = gross daily precipitation amount (mm)

c = coefficient of initial abstractions

= 0.25 (*ZIMsched* default value)

S = potential maximum water retention of the soil, taken as the soil water deficit below porosity (mm)

(S is calculated for the top 0.250 m of soil as a default in *ZIMsched*)

A major difference between Equation 3 (Schulze, 1995) and the original SCS stormflow equation (USDA, 1985) is that the potential maximum retention, S, is a soil water deficit calculated by daily water budgeting techniques. The soil water deficit is taken as the difference between water retention at porosity and the actual soil water content just prior to the rainfall event. Equation 3 has been well tested (Schulze 1995) including tests on sugarcane catchments (Smithers, Schulze, and Schmidt, 1997). The tests on the sugarcane catchments formed the basis for the recommended *ZIMsched* default values for c and the depth for which S is calculated.

Drainage

If at the end of a day, if the soil water content is still above the drained upper limit (DUL) or field capacity, drainage of water from the profile is initiated. The drainage rate is calculated according to equation 4 (Ritchie, 1986), *viz*.

$$D_d = (\theta_t - \theta_{DUL}).\, K_s \quad \text{for} \quad \theta_t > \theta_{DUL} \qquad \text{Eq. 4}$$

where D_d = depth of drainage water (mm.day-1)

θ_t = actual soil water content (mm equivalent)

θ_{DUL} = soil water content at drained upper limit, DUL (mm equivalent)

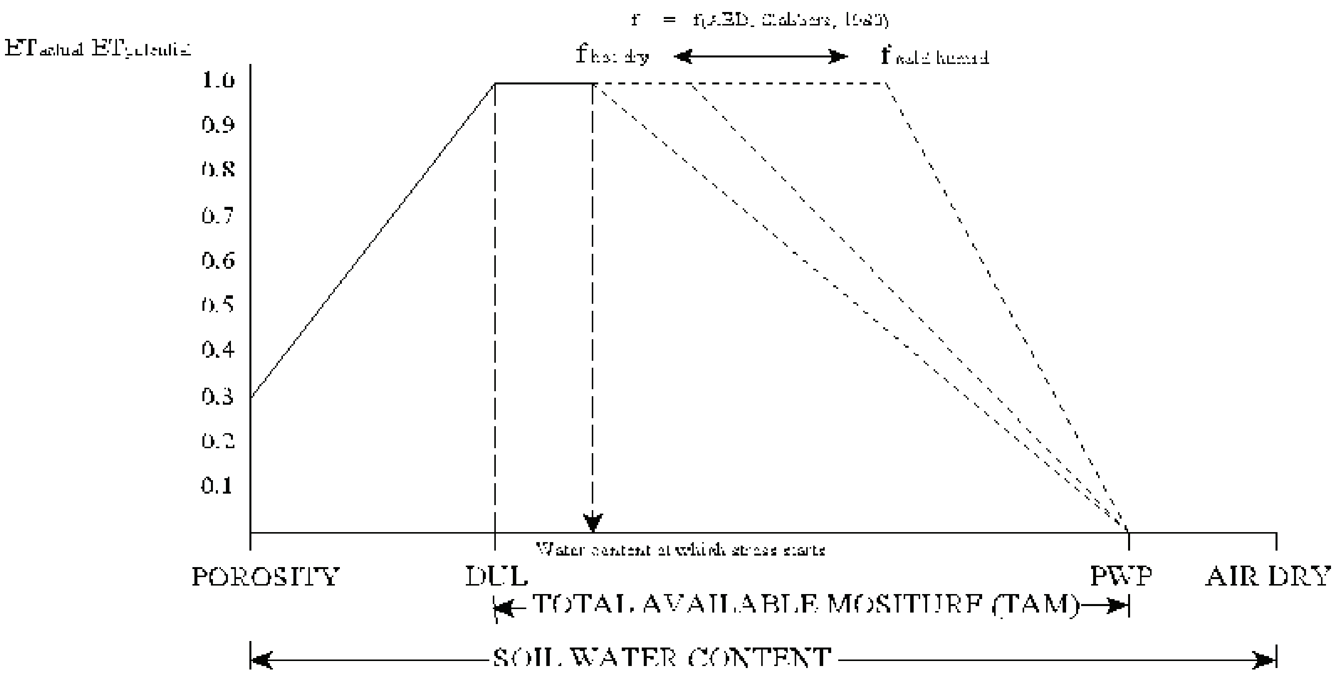

Figure 2. Interrelationships used in *ZIMsched* between soil water content and the ratio of $ET_{actual} : ET_{potential}$. 'f' is the fraction of TAM at which water stress starts (after Schulze, 1995).

K_s = saturated drainage coefficient

= $(\theta_{po} - \theta_{DUL})/\theta_{po}$ (as the default value)

θ_{po} is the soil water content at porosity (mm equivalent)

Drainage can take place over a number of days during which the plant can extract water but at a slightly reduced rate due to poor aeration (cf. Figure 2). The amount of drainage and the duration of drainage is dynamic, dependent on soil characteristics, antecedent soil water and the magnitude of the rainfall or irrigation event resulting in excessive soil water. Thus when compared to many other water budgeting algorithms which assume a fixed drainage time, often of only one day, the time for the soil to drain to field capacity (or the DUL), as determined in *ZIMsched*, is highly variable. This is a very important aspect, as the tendency to over-simplify drainage assumptions and assume drainage to field capacity in a fixed time period, which is often too short, can lead to a snowballing cycle of over-irrigation and poor root aeration.

Effective Rainfall

Effective rainfall is defined as that amount of rainfall that enters into the soil profile and is available for use by the crop. In *ZIMsched*, effective rainfall is calculated on a daily basis dependent on the runoff, drainage and ET relationships described in this paper.

Crop Yield Estimate

The crop yield estimate is based on a robust relationship between actual ET and sugarcane yield that was derived by Thompson (1976) using data from Hawaii, Australia, Mauritius, Mt Edgecombe, Chakaskraal and Pongola. In *ZIMsched*, the ET used in this relationship is affected by soils, climate and irrigation management and is calculated on a daily basis using the water budgeting relationships described in this paper. Although simple, this yield relationship has stood the test of time, and when metricated can be expressed as (Schulze, *et al.*, 1995):

$$Y_b = 9.53(ET_{accum}/100) - 2.36 \quad \text{Eq. 5}$$

where Y_b = benchmark sugarcane yield estimate ($t.ha^{-1}$)

ET_{accum} = accumulated actual ET as estimated on a daily basis in *ZIMsched* (mm)

ZIMsched: Operational Description

Input information

The various components of the water budget and the crop yield estimate are represented in columns in a spreadsheet as shown in Figure 3. The required input information, *viz*.

- maximum temperature,
- minimum temperature,
- A-pan evaporation,

SOIL DESCRIPTIVE PARAMETERS				
Sand %	70.00	Porosity =	0.400	m/m
Silt %	10.00	DUL =	0.230	m/m
Clay %	20.00	PWP =	0.116	m/m
Pb	1.50			
Texture	SaCIL	Depth =	0.8	m
Drainage	bad	TAM =	100	mm
Saturated Drainage Coefficient			0.170	

'ZIMSCHED 1.1' IRRIGATION SCHEDULING SPREADSHEET (copyright 2000 by N.L. Lecler, ZSAES, all rights reserved)

Date	DAILY MEASUREMENTS					CALCULATIONS												
Field No. F10/11 95006	Max Temp (°C)	Min Temp (°C)	Apan (mm)	Rain (mm)	Irrig Water (mm)	Accum Thermal Time (°C.d)	Est Crop Coeff.	Est Runoff (mm)	Est Potential ET (mm)	Est Actual ET (mm)	Est Drainage (mm)	Soil Water After Drainage (mm)	Soil Water at which Stress Starts (mm)	Est Yield Accum ($t.ha^{-1}$)	ET Ratio	Potential Runoff Store	Stabber's 'f'	Root factor
01/05/1999	27.9	11	10	0	0	7.45	0.30	0.00	2.98	2.98	0.0	-3.0	-14.9	0	1.00	42.6	0.63	0.40
02/05/1999	30	11.5	4.2	0	0	16.2	0.30	0.00	1.25	1.25	0.0	-4.2	-32.1	0	1.00	45.4	0.20	0.40
03/05/1999	31.4	11.2	3.65	0	0	25.5	0.30	0.00	1.09	1.09	0.0	-5.3	-36.6	0	1.00	46.6	0.09	0.40
04/05/1999	31	11.8	3.8	0		34.9	0.30	0.00	1.14	1.14	0.0	-6.5	-35.2	0	1.00	47.6	0.12	0.40
05/05/1999	31.6	12	5	4.8		44.7	0.30	0.00	1.50	1.50	0.0	-3.2	-27.4	0	1.00	48.7	0.32	0.40
06/05/1999	20.2	17.7	0.7	0.2		51.65	0.30	0.00	0.21	0.21	0.0	-3.2	-38.1	0	1.00	45.6	0.05	0.40
07/05/1999	23.8	16.4	2.65	0		59.75	0.30	0.00	0.80	0.80	0.0	-4.0	-38.2	0	1.00	45.6	0.05	0.40
08/05/1999	25.4	10.8	3.35	0		65.85	0.30	0.00	1.02	1.02	0.0	-5.0	-38.3	0	1.00	46.3	0.05	0.40
09/05/1999	27.6	10.2	2.9	0		72.75	0.30	0.00	0.88	0.88	0.0	-5.9	-38.5	0	1.00	47.3	0.05	0.40
10/05/1999	26	14	2.85	0		80.75	0.31	0.00	0.87	0.87	0.0	-6.7	-38.6	0	1.00	48.1	0.05	0.41
11/05/1999	26.2	11.4	4.35	45.0		87.55	0.31	12.20	1.34	1.34	4.2	20.5	-31.7	0	1.00	48.9	0.22	0.41
12/05/1999	26.4	10.2	2.95	0.0		93.85	0.31	0.00	0.91	0.81	3.4	16.3	-38.9	0	0.89	23.4	0.05	0.41
13/05/1999	29.7	10	3	0.0		101.7	0.31	0.00	0.93	0.85	2.6	12.9	-39.1	0	0.92	27.3	0.05	0.41
14/05/1999	26.3	14.2	4.7	0.0		109.95	0.31	0.00	1.47	1.37	2.0	9.5	-30.0	0	0.93	30.6	0.28	0.41
15/05/1999	26.8	11.2	2.95	0.0		116.95	0.31	0.00	0.93	0.88	1.5	7.2	-39.5	0	0.95	33.7	0.05	0.42
16/05/1999	26.2	11.2	3.55	0.0		123.65	0.32	0.00	1.12	1.08	1.0	5.1	-39.2	0	0.96	35.9	0.06	0.42
17/05/1999	23.2	16	1.6	2.0		131.25	0.32	0.00	0.51	0.50	1.1	5.4	-39.9	0	0.97	37.9	0.05	0.42
18/05/1999	22.4	16.4	1.55	0.0		138.65	0.32	0.00	0.50	0.48	0.8	4.1	-40.2	0	0.97	37.5	0.05	0.42
19/05/1999	26	15	3.5	0.0		147.15	0.32	0.00	1.13	1.11	0.5	2.5	-40.5	0	0.98	38.8	0.05	0.43
20/05/1999	28.4	12	3.05	0.0		155.35	0.33	0.00	1.00	0.98	0.3	1.2	-40.8	0	0.99	40.3	0.05	0.43
21/05/1999	29.6	13	3.8	0.0		164.65	0.33	0.00	1.25	1.25	0.0	0.0	-38.1	0	0.99	41.4	0.12	0.43
22/05/1999	28	14.3	2.4	0.0		173.8	0.33	0.00	0.80	0.80	0.0	-0.8	-41.5	0	1.00	42.6	0.05	0.44
23/05/1999	33	13	4	0.0		184.8	0.34	0.00	1.35	1.35	0.0	-2.2	-37.1	0	1.00	43.3	0.16	0.44
24/05/1999	27	15.6	2.4	0.0		194.1	0.34	0.00	0.82	0.82	0.0	-3.0	-42.3	0	1.00	44.6	0.05	0.45
25/05/1999	26.5	12.5	2.85	0.0		201.6	0.35	0.00	0.98	0.98	0.0	-4.0	-42.7	0	1.00	45.3	0.05	0.45

Figure 3. *ZIMsched*: Spreadsheet columns (for a crop planted 01/05/1999).

- rainfall, and
- irrigation water applied

are also columns in the spreadsheet (cf. Figure 3).

The only other input information required for *ZIMsched* is the:

- Total Available Moisture (TAM) of the soil for the field in question, and
- the saturated drainage coefficient.

Default values for these are estimated in *ZIMsched* based on soil textural analysis and bulk density estimates using relationships derived by Hutson (1984) and Ritchie (1986) respectively. They can also be input directly or modified by a user if better information is available.

Fields Representation

Numerous inter-dependent fields can be represented in a single spreadsheet file, with each field on a different notebook sheet. For example, a user may have a centre pivot divided into four sectors, with each sector planted at different times of the year. In *ZIMsched* each sector could be represented in the same file but on a different notebook sheet. Input information for maximum temperature, minimum temperature, A-pan evaporation and rainfall (if desired) need only be entered once in the first notebook sheet as the notebook cells for a particular date on the first sheet are linked to the corresponding notebook cells for the same date in all the other notebook sheets so that the input data is carried through automatically and only needs to be entered once. The components of the water budget are calculated and updated automatically once changes to input information are made. On large estates with networked computers, weather data need only be entered in a single spreadsheet file for whole sections of the estate. The cells in this file can then be automatically linked to cells for the corresponding date in all the *ZIMsched* files used for fields on that section. Links between *ZIMsched* and geographical information systems (GIS) are being investigated in collaboration with a large sugar estate in Zimbabwe.

Determination of irrigation water applications

When using *ZIMsched*, a user simply enters recorded daily values for maximum and minimum temperature, A-pan, rainfall and irrigation water applications and observes changes to the estimated soil water status and the date when the estimated soil water is expected to reach a level at which an irrigation water application is needed. In order to extrapolate, a user can use long term mean values for weather data or use the in-built spreadsheet functionality to calculate the mean of the previous 'x' days and extrapolate using these values. In the sugar industry in the lowveld of Zimbabwe representative recorded values for daily maximum and minimum temperature and A-pan are available from the Zimbabwe Sugar Association Experiment Station or from one of the three large Estates. Users must record their own rainfall and irrigation water applications. In order to simplify the appearance of *ZIMsched*, users can elect to hide components of the water budget that may not be of interest or that may be confusing using the 'columns hide' facility in spreadsheets.

IRRIGATION SUMMARY								
Date	FIELD 1		FIELD 2		FIELD 3		FIELD 4	
	Area (ha)	10.3	Area (ha)	8.7	Area (ha)	14.5	Area (ha)	6.1
	Target mm	30	Target mm	30	Target mm	50	Target mm	40
	Soil Water (mm)	Action	Soil Water (mm)	Action	Soil Water (mm)	Action	Soil Water (mm)	Action
02/11/1999	-34	irrig	-25	wait	-33	wait	-5	wait
03/11/1999	-8	wait	-34	irrig	-40	wait	-8	wait
04/11/1999	-16	wait	-42	irrig	-45	wait	-10	wait
05/11/1999	-27	wait	-51	irrig	-50	irrig	-14	wait
06/11/1999	-30	irrig	-54	irrig	-53	irrig	-15	wait
07/11/1999	-35	irrig	-24	wait	-57	irrig	-17	wait
08/11/1999	-5	wait	-29	wait	-59	irrig	-18	wait
09/11/1999	-8	wait	-31	irrig	-61	irrig	-19	wait
10/11/1999	-13	wait	-36	irrig	-64	irrig	-21	wait
11/11/1999	-22	wait	-46	irrig	-67	irrig	-24	wait
12/11/1999	-28	wait	-52	irrig	-69	irrig	-26	wait
13/11/1999	-36	irrig	-58	irrig	-71	irrig	-28	wait
14/11/1999	-10	wait	-63	irrig	-73	irrig	-30	wait
15/11/1999	-19	wait	-68	irrig	-75	irrig	-31	wait
16/11/1999	-28	wait	-72	irrig	-77	irrig	-33	wait
17/11/1999	-37	irrig	-75	irrig	-79	irrig	-34	wait
18/11/1999	-11	wait	-77	irrig	-80	irrig	-36	wait
19/11/1999	-5	wait	-67	irrig	-69	irrig	-25	wait
20/11/1999	-5	wait	-67	irrig	-69	irrig	-22	wait

Figure 4. Notebook sheet showing soil water status for selected fields.

Other ZIMsched utilities

Additions or modifications to *ZIMsched* to suit user requests are easily added. For example, a request by users has been to have a summary notebook sheet which shows on one page the estimated soil water status for a particular grouping of inter-dependent fields. This is shown in Figure 4. Another request is to have a notebook sheet which has summaries of weekly water orders that depend on field areas, application amounts, conveyance and balancing dam losses. Conveyance losses are estimated as a percentage of water conveyed and farm balancing dam losses are estimated based on the surface area of the dam and daily A-pan values adjusted for open water bodies (Schulze, *et al*., 1995) The information in these summary sheets is generated automatically, based on the water budgeting notebook sheets and user input regarding actual and expected irrigation applications.

Crop yield benchmarks and forecasts

ZIMsched has powerful facilities for yield forecasting and benchmarking. Yield estimates for selected historical years can easily be compared to corresponding estimates for the present season. The present season can be extrapolated to a harvest date assuming various climate scenarios, for example, using long term mean weather data or weather data from historical seasons associated with particularly good or bad climatic conditions. Both potential yields and actual yields can be compared. Potential yields are based on ET estimated with no soil water stress effects and actual yields are based on ET estimates as influenced by soil water stress caused by too much or too little water.

Useful in-built spreadsheet functions

The in-built charting options in spreadsheets are a particularly useful tool and enable various charts to be quickly updated or designed. For example, a chart showing estimated soil water status, the soil water status at which water stress is initiated and the associated rainfall and irrigation applications is shown in Figure 5. Another useful chart option shows the soil water status of a particular inter-dependent field grouping enabling a user to see at a glance the relative wetness of the selected fields. *ZIMsched* has many other management applications, for example, managing and recording fertilizer applications so that chances of leaching are minimised, or displaying day-lengths so that a crop may be deliberately stressed when day-lengths may otherwise promote undesired flowering. Seasonal summaries and statistics of the various components of the water budget, for example, irrigation water applications, are easily calculated in *ZIMsched* using the in-built spreadsheet functions, for example, “@avg”, for averaging, or “@sum”, for summation.

Conclusions

ZIMsched is a robust, scientifically sound and yet simple irrigation management and yield forecasting tool. It has been developed in Zimbabwe but should have wide application with minor, if any, modifications. *ZIMsched* has:

- excited potential users because ease of use is complimented by accuracy and the power to address major challenges - users have experienced a high degree of familiarity and competency within thirty minutes of using the tool. This is believed to be a key aspect to successful technology transfer;
- been developed to be a multi-level tool. This means that optimal use of available data/information is made, but the facility to incorporate more complex options if the required data/information becomes available is included;
- incorporated robust algorithms to account for the components of a water budget that are of major importance to irrigation, and yet which are often ignored, over-simplified or over-complicated, *viz*. runoff, drainage, effective rainfall

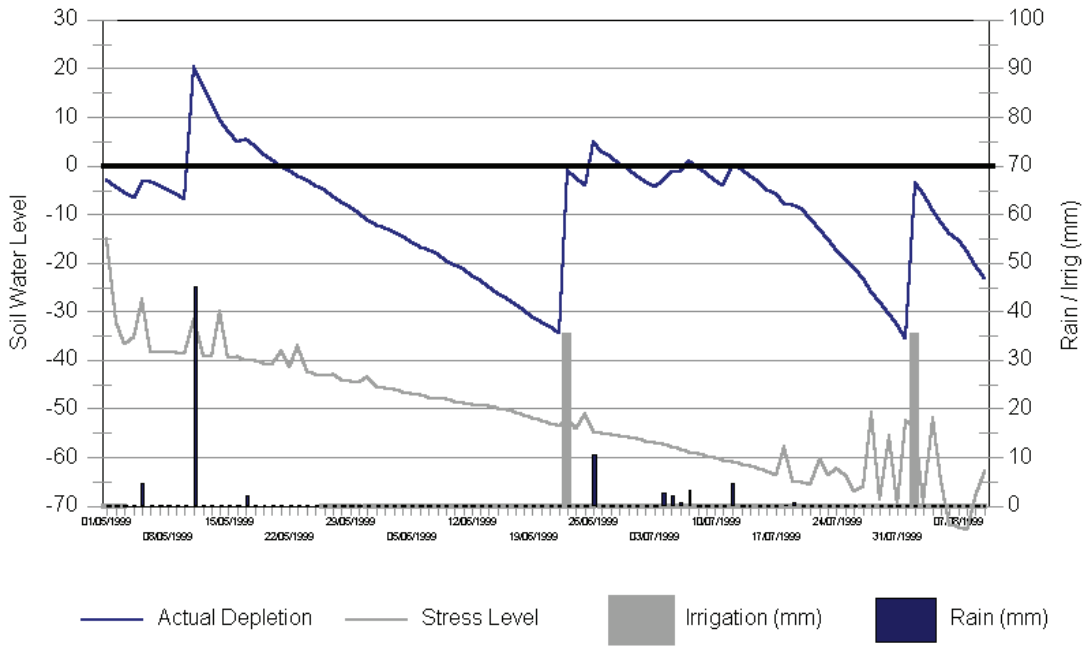

Figure 5. Variations of estimated soil water status, soil water stress level, irrigation and rainfall.

and evaporation under conditions of excess or deficient soil water;

- been developed to be flexible enough to be reset/adjusted with ease, should field soil water observations indicate a need, for example, if a drainage problem becomes apparent, or a disease or nutritional deficiency results in conditions different to the norm;
- the facility to include various management strategies, for example, controlled soil water deficits at certain stages under water limited conditions, or to inhibit flowering;
- efficient options for managing input data and executing calculations in order that operational time is minimised so that time can be freed for information analysis;
- been developed as an extension package that should result in significant gains in water use efficiency and crop yield.

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