DEVELOPMENT OF AN IRRIGATION POLICY TO OPTIMISE SUGAR PRODUCTION DURING SEASONS OF WATER SHORTAGE

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Abstract

Severe water restrictions in Zimbabwe necessitated a review of local experimental evidence in order to develop an irrigation policy to optimise sugar production. Ratoon crop water requirements in the developmental stages of germination and tillering, stalk growth and maturation were examined. A water budget was constructed which demonstrated that irrigation scheduling using the revised policy provided a potential saving in water use of 32% when compared with conventional practices. Comparisons of estate sugar production in successive years showed that adoption of the strategy did not reduce estimated recoverable crystal (ERC) yield and resulted in a 20% saving in total water applied. The need for further irrigation research is discussed.

Introduction

In 1981/82 and 1982/83 the Zimbabwe Lowveld sugarcane production area experienced severe droughts with rainfall being 69% and 60% of the long term mean for the respective seasons. Additionally, in the latter season, mean daily summer temperatures were 1,8°C above normal from December to June and evaporation 16% greater for the same period.[8] Heavy irrigation demand during this period, coupled with inadequate replenishment of water storage systems, resulted in reduced water allocations to sugarcane estates for the water year beginning 1st October, 1983. Mkwasine Estate was the most severely affected of the three major producers in the Lowveld, being restricted to an annual water allocation of 65% of normal. However, even prior to the imposition of these constraints, it was clear that the water allocation from Manjirenji Dam would be inadequate for the Estate's cropping programme during the winter of 1983. Clearly, an urgent examination of irrigation policy was necessary if sugar production was not to be limited by the water shortage.

Review of experimental evidence

Thompson[4] comprehensively reviewed the use of water by sugarcane with particular reference to Southern African conditions and subsequently discussed irrigation practices.[5] He suggested that a water duty of approximately 2 300 ha/cumec at 100% efficiency was appropriate under full irrigation at Pongola, a similar figure to that reported by Cackett[1] for Zimbabwe. Assuming an optimistic level of efficiency of 80% for planning purposes such a water duty would have necessitated the exclusion of about 1 500 ha or 30% of the estate sugarcane crop. The very heavy prospective costs of re-establishment, whenever normal water supply was restored, made it necessary to review in detail the irrigation strategy employed against available and relevant evidence in order to maintain productivity in the face of the restricted water supply.

Considerable local experimental evidence was available from the Zimbabwe Sugar Association Experiment Station and in examining this evidence it was apparent that meaningful physiological growth stages had been defined for sugarcane under local conditions. The crop's annual growth could be divided into three development phases:

- germination and tillering stage
- stalk growth stage
- maturation stage

Some relevant irrigation experimental evidence was available for each of these growth stages. Accordingly, this evidence was reviewed stage by stage in order to select the most advantageous irrigation regime within each growth stage. The most favourable regimes were then linked together to form the revised policy for the whole crop.

Germination and tillering stage

Growth studies in Zimbabwe[7] had shown that germination and tillering of ratoon cane was temperature-dependent. Peak tiller numbers were recorded for autumn (April) harvests at 16 weeks after cutting, for spring (August) harvests at 12 weeks after cutting, and for summer (November) harvests at 8 weeks after cutting. Rapid stalk elongation was found to commence at 24, 12 and 8 weeks after cutting respectively. Furthermore, it was concluded that the commencement of stalk elongation was coincident with primary tillers having at least 5 unfurled leaves and with mean daily temperatures attaining a threshold value of 18,5°C.

For April harvests leaf development, whilst slow, exceeds 5 open leaves before the threshold temperature is attained in late August in Zimbabwe. In August harvests mean daily temperatures exceed 18,5°C early in the tillering phase but development to the 5 leaf stage is relatively slow (12 weeks). In summer the temperature threshold is not relevant and rapid stalk elongation is delayed until 8 weeks after cutting when the 5 unfurled leaf stage is reached.

An irrigation trial[6] relevant to this growth stage was harvested in late July annually and irrigated to field capacity immediately afterwards, followed by a light irrigation a month later to incorporate fertiliser. Treatments consisted of delaying the next irrigation until open pan evaporation ranging from 46 mm to 278 mm had accumulated. Regular irrigation scheduling was practised thereafter.

In the most severe treatment, regular irrigation did not commence until 10 weeks after cutting in the second ratoon and 15 weeks after cutting in the third ratoon. At harvest there was no significant difference in cane yield, estimated recoverable crystal % (ERC %) or ERC yield between the treatments (Table 1).

Wilting was observed in the driest treatments but evidently without significant effect on yield nor on millable stalk populations. However, an annual saving of 216 mm of irrigation water was obtained between the driest treatment and the treatment irrigated most frequently.

This experiment was harvested annually in late July when, as growth studies indicate, the period from ratooning to the commencement of rapid stalk elongation is 12 to 14 weeks. This equates approximately with the longest stress period recorded in the experiment.

A further trial, designed to determine the effect of moisture stress at various stages of crop growth, was harvested in mid-September.[10] No significant reduction in ERC yield was re-

TABLE 1

Effects of predetermined periods of stress before the commencement of regular irrigation in newly ratooned NCo 376 in Zimbabwe (Mean of 3 crops).

Accumulated open pan evaporation before first regular irrigation mm	Total rainfall and irrigation mm	Cane yield t/ha	ERC %	ERC yield t/ha	Cane yield per unit water t/ha/100 mm	ERC yield per unit water t/ha/100 mm
46	2 048	131,7	13,10	17,25	6,43	0,84
93	2 014	129,8	13,07	16,96	6,44	0,84
139	1 980	137,9	12,55	17,31	6,96	0,87
186	1 946	129,8	12,81	16,63	6,67	0,85
232	1 895	131,5	13,24	17,41	6,93	0,91
278	1 832	129,6	13,44	17,42	7,07	0,95

(Unpublished data Zimbabwe Sugar Association Experiment Station Chiredzi).

ported by delaying regular irrigation for 13 weeks after harvest, provided standard irrigation scheduling was practised thereafter. A reduction of 204 mm in water applied was recorded.

In the Estate's predicament and in the absence of other relevant experimental evidence, it was not unreasonable to expect that, in the case of autumn and summer harvests, the period between cutting and the commencement of stem elongation could be stressed similarly without significant loss of yield.

Accordingly, with modifications after Ellis,[2] the following schedule for the commencement of regular irrigation after ratooning was constructed.

Month of harvest	Commencement of regular irrigation	
April	Mid-August	Daily mean threshold temperature of 18.5°C reached by this time
May	Mid-August	
June	12 weeks after harvest	Primary tillers have reached 5 unfurled leaves by this time
July	12 weeks after harvest	
August	12 weeks after harvest	
September	10 weeks after harvest	
October	8 weeks after harvest	
November	8 weeks after harvest	
December	8 weeks after harvest	

To exploit this phenomenon of diminished sensitivity to water stress in the early growth phase it was accepted that the soil was to be irrigated to field capacity after ratooning and again when regular irrigation commenced. Fertiliser applications had to be timed to coincide with these strategic irrigations.

It was further accepted that the newly planted cane would require more frequent standard irrigation to allow for the slower development of a root system and to sustain tiller production. Similarly, the irrigation practice was to be modified in instances of very shallow or light textured soils with limited storage of water in the rooting zone.

Stalk growth stage

It was assumed necessary to adopt an irrigation regime during this period to optimise the growth of stalks, the harvestable portion of the crop. Thompson[4] indicates that water use by adequately watered cane is related to pan evaporation by an E_t/E_0 ratio of 1,0 reducing to 0,8 in certain cases and that generally cane yields are maximised when irrigation is scheduled at a ratio of 1,0. Other work, particularly that of Gosnell and Lonsdale conducted in Zimbabwe,[3] showed that in burnt ratoon cane, crystal yield could be optimised by a less generous irrigation scheduling regime.

In their experiment the treatments were designed to vary the intervals between irrigation, maintaining the irrigation applied at 50,8 mm. The treatments were defined by "pan factors" of 1,0; 0,84; 0,68; 0,53 and 0,37. The accumulated open pan evaporation between irrigations for each treatment was determined by dividing the amount of water applied by the "pan factor" and hence irrigation intervals were 50,8; 60,4; 74,2; 96,0 and 135,4 mm of open pan evaporation respectively.

The responses in cane yield over five ratoon crops indicated a marginal increase in cane yield of 1% between the 0,84 and 1,0 "pan factor" treatments, but because of better quality in the 0,84 treatment there was no significant difference in recoverable sucrose yield between the two treatments. The 0,84 "pan factor" treatment also resulted in near optimum returns per unit of water (Figure 1).

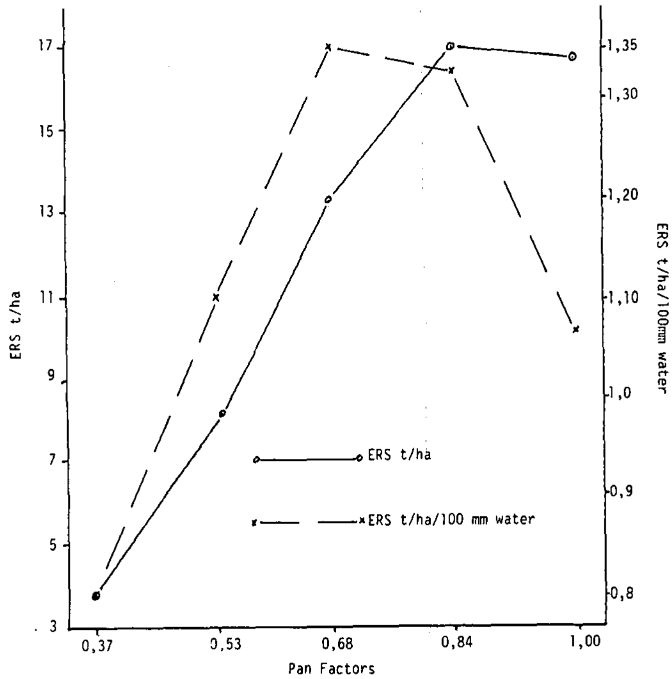

FIGURE 1 Response to irrigation at varying pan factors, of sucrose yield per unit area and per unit water applied (Burnt ratoon cane) for 5 ratoons in Zimbabwe. (Gosnell and Lonsdale[3]).

These treatments were only dried off to enable harvesting to take place. A further treatment irrigated at a "pan factor" of 0,84 and dried off for 14 weeks at a "pan factor" of 0,6 resulted in similar sucrose yields to the 1,0 and 0,84 treatments with a considerable reduction in water use.

In order to optimise productivity on the Estate per unit of land and per unit of water during the stalk growth phase, it was decided to adopt a policy of irrigation scheduling based on a "pan factor" of 0,8 and to aim at an irrigation application of 50 mm when 63 mm of open pan evaporation was recorded with provision to modify the schedule on shallow or light textured soils.

Maturation stage

Numerous drying-off trials have been conducted in Zimbabwe with variable results but generally indicating that drying-off results in a small increase in ERC yield but, more importantly, significant savings in irrigation. Recent work[9] shows that the most effective method of drying-off is a complete cessation of irrigation rather than a reduction in frequency. In spring harvested crops a period of nearly three months before harvest without irrigation did not reduce ERC yield. During this period the predicted accumulated open pan evaporation was 3 × TAM (Total Available Moisture) of the soil (Table 2).

Using this evidence as a guide, a drying-off schedule for expected harvest dates was developed based on known soil moisture characteristics and mean daily evaporation values.[2] The schedule permits the last irrigation to be calculated in advance, allowing the accumulated evaporation to be 3 × TAM mm for the drying-off period (Appendix 1).

The drying-off periods are shorter on shallow or light textured soils and in summer, than on the deeper, heavier soils and in winter. In the experiment cited some wilting occurred towards the end of the drying-off period but this did not result in a diminution of ERC yield.

Method

Water budget

The irrigation criteria selected as most favourable for each growth stage were combined in sequence to form the revised irrigation policy which was then used to construct a water budget. These criteria were as follows:

- Soils were to be irrigated to field capacity after harvest with an application of 100 mm which is approximately the mean TAM.
- A period of stress, determined by the harvest date, was to be imposed before the commencment of rapid stalk elongation (see germination and tillering section). At this time soils were again to be irrigated to field capacity.
- Regular irrigation scheduling in the stalk growth stage was to be based on a pan factor of 0,8 with an irrigation of 50 mm.
- The commencement date of drying-off was calculated to allow for the predicted accumulated open pan evaporation prior to harvest to be 3 × TAM.

The derived budget is presented in Appendix 2 and for comparative purposes the generally recommended estimate of water requirements[1] based on standard scheduling by canopy development and an E_t/E_o ratio of 1,0 at fully canopy, followed by a moderate drying-off period is also shown in Appendix 3. For both budgets the long term mean rainfall is used and effectiveness is taken as 50%. Given an irrigation efficiency of 100%, water duty in the revised budget is estimated at 3 337 ha/cumec. This reflects an increase of 47% in land area which can be utilized by adopting the revised water duty.

The mean water requirements for the two budgets for each of the three stages of ratoon growth were as follows:

	Standard budget mm	Revised budget mm	Savings in water mm
Germination and tillering stage	341	200	141
Stalk growth stage	913	745	168
Maturation stage	134	—	134
	1 388	945	443

The revised budget gives a water saving of 32% of the standard practice.

For planning purposes allowances were made for infield inefficiency (15%) and for domestic requirements and distribution and storage losses (10%) giving a total system efficiency of 75%.

Large savings in water appeared to be possible if the revised strategy was adopted. However, although based on experimentally tested results for each growth phase, there was no certainty that yields would be maintained at an acceptable level where the new irrigation regime was applied as a whole. Nevertheless, with the critical water shortage faced by the Estate it was necessary to assume that the revised strategy would be successful, minimising a costly field abandonment programme.

Irrigation control

The implementation of the new water policy required an increase in irrigation efficiency with strict control of scheduling and application in the field. Of the 5 000 ha of sugarcane on the Estate approximately 60% is in-row furrow irrigated while the balance is sprinkler irrigated.

The fields under furrow irrigation are principally composed of moderately deep (0,8 to 1,0 m) sandy clay loams over sandy clays with an approximate TAM of 100 mm. The sprinkler irrigated fields are lighter textured or with a greater gravel content and shallower. The TAM of these soils is estimated at 70 mm.

Scheduling in the germination and tillering phase was straight forward with an irrigation soon after harvest and another at the start of rapid stalk elongation. On the lighter textured soils under overhead irrigation intermediate irrigations were allowed providing the total application of 200 mm budgeted for the phase was not exceeded.

During the stalk growth phase irrigation was scheduled at a pan factor of 0,8. On the heavy textured deep soils 50 mm was the desired nett application when accumulated open pan evaporation was 63 mm. On the lighter textured and shallower soils this application was reduced to 36 mm nett against an accumulated pan evaporation of 45 mm. The inadequacy of such generalised scheduling was recognised by allowing fields that were known to be atypical to be irrigated according to revised estimates of soil water availability.

The evaporation data used for scheduling were long term means but, when current evaporation rates differed by more than 20% from the mean, the frequency of irrigation was adjusted accordingly.

Periods of rainfall less than 15 mm were ignored for scheduling purposes. Irrigation was suspended when rainfall exceeded 15 mm and recommenced when the accumulated evaporation after the rainy period was equivalent to the rainfall recorded in that period. The current irrigation cycle was abandoned when falls were greater than 50 mm and a new cycle started in accordance with routine scheduling. Soil augering was used as a further aid in determining the date of resumption of irrigation after rainfall.

The last irrigation before drying-off was timed according to the schedule given in Appendix 1.

TABLE 2

Effect of drying-off by cessation of irrigation at pre-determined periods before harvest in September in Zimbabwe (Mean of 4 crops).

Predicted accumulated open pan evaporation at harvest	Accumulated Eo between last irrigation and harvest mm	No. of days before harvest of last irrigation	Total rainfall and irrigation mm	Cane Yield t/ha	ERC %	ERC Yield t/ha	Cane Yield per unit water t/ha/100 mm	ERC Yield per unit water t/ha/100 mm
58 mm = 0.5 TAM	42	10	1 945	147,8	13,59	20,10	7,62	1,04
115 mm = 1.0 TAM	81	21	1 894	147,3	13,55	19,98	7,80	1,06
173 mm = 1.5 TAM	135	34	1 831	146,9	13,57	19,93	8,05	1,10
230 mm = 2.0 TAM	186	45	1 780	148,2	13,77	20,43	8,37	1,15
288 mm = 2.5 TAM	240	61	1 729	147,1	13,72	20,19	8,54	1,17
345 mm = 3.0 TAM	300	78	1 677	145,4	13,82	20,12	8,71	1,21

It was essential to ensure that the quantity of water applied to a field was not significantly greater than that budgeted. Because some inefficiency was inevitable in the application of the water to the field an additional 15% was allowed in the planning work. In order to optimise the efficiency of application, the maintenance and the management of the sprinkler system was improved to minimise wastage and increase the uniformity of distribution of water. Greater attention was necessarily directed at the furrow irrigation as this system is generally less efficient than overhead irrigation.

It was not possible to adjust furrow lengths and gradients in existing sugarcane fields but the furrow shape was widened to between 0,8 and 1,0 m in order to increase the contact area. This, together with heightening the interrow ridge, was necessary in order to contain the large flow rates of up to 10 ℓ/s required to obtain the moderate 50 mm irrigations.

Despite these alterations, practical tests showed that there was an unacceptably large variation in irrigation depth within fields and to overcome this a control was instituted in which the actual time taken to irrigate a hectare, given the known flow rate in the field edge feeder, was compared with the calculated time to apply 50 mm over a hectare. Corrections were then possible by changing the furrow flow rates in order to approach the required depth of application more closely. Such corrections could be made within an irrigation cycle if the amount applied was insufficient or in the succeeding irrigation if the previous irrigation had been excessive. This control measure proved to be very successful. Attention was then turned to ensuring an even distribution of water along the length of each furrow by the conventional controls.

Results of the revised irrigation practice

The results obtained on the Estate can be gauged by a comparison of yields and water used (Table 3). The crop harvested in 1983 had been grown on the standard irrigation recommendations except with the revised drying-off practice. The 1984 crop was irrigated throughout the year according to the revised strategy.

TABLE 3

Comparison of water applied and sugar production on Mkwasine Estate 1983 and 1984.

	1983 Harvest	1984 Harvest	Difference %
Effective rainfall mm 1 October to 30 September	131	227	+ 73
Irrigation mm 1 October to 30 September	1 502	1 075	− 28
Total water mm 1 October to 30 September	1 633	1 302	− 20
Cane yield t/ha	118,9	114,0	−4,1
ERC %	12,16	13,00	+ 6,9
ERC yield t/ha	14,52	14,82	+ 2,1
Cane yield t/ha/100 mm water	7,28	8,75	+ 20
ERC yield t/ha/100 mm water	0,88	1,13	+ 28

There was a reduction in cane yield in 1984 of 4,1% and this was not unexpected as Gosnell and Lonsdale[3] had found a similar decrease. However, there was an increase of 6,9% in ERC % and an increase of 2,1% in ERC yield in 1984.

The benefits were greater when examined against the return per unit of water used. Total water used (rainfall and irrigation) was 20% less in 1984 than in 1983, for the same hectarage of cane. Efficiency of production of cane per unit of water increased by 20% and of crystal by 28%.

It was clear therefore that there was no yield reduction on account of the modified strategy but there were marked reductions in water use. Thus the overall objective of maintaining Estate productivity against a diminished water supply had been met.

Discussion and Conclusions

The experience gained, following the review of relevant irrigation experimental evidence appropriate to the growth stages of sugarcane and the subsequent development and application of the preferred irrigation strategy, has emphasised requirements for further research information.

An interesting phenomenon which was observed in Estate fields abandoned after cutting in 1984 was that subsequent germination and tillering was not completely dependent on irrigation. Cane which had been subjected to drying-off before harvest and which received no further irrigation nor meaningful rainfall tillered profusely, particularly on deep heavy textured soils. Tillers did not appear to suffer from severe moisture stress until near the expected date of commencement of rapid stalk elongation. Greater knowledge of the effect of this phenomenon holds promise for further savings in irrigation requirement.

The evidence to support the practice of minimising irrigation between harvest and the onset of rapid stalk elongation derives from separate experiments harvested in winter and spring. There is no such evidence available in respect of autumn and summer harvests and extrapolation into these seasons was undertaken recognising this deficiency. Verification of the validity of the strategy adopted is important since it is readily acknowledged that the evidence upon which it is based is scant.

There is also a need for experimental resolution of the most appropriate irrigation regime in the stalk growth stage. The evidence available is somewhat contradictory for this phase and, since it is the period of maximum water consumption, improved effectiveness of irrigation would be reflected in significant savings. A clear distinction between maximising either cane yield or ERC yield needs to be made when considering the irrigation regime to be adopted in this phase.

The experiments in the maturation phase were designed to examine yield responses to drying-off to a maximum accumulated pan evaporation of 3 × TAM only, when no reduction in ERC yield was observed. This suggests that the upper limit of drying-off has not been tested and a longer period is feasible.

Adverse comments on the incidence of withered stalks and related low purity values in late season harvests were made by local millers and it was suggested that this may have been due to the extended drying-off period. However, this phenomenon was a particularly troublesome feature in lodged cane and required careful control at harvest to exclude stalks of poor physical quality from cane consigned to the mills. Despite the presence of these withered stalks, satisfactory ERC % values were obtained on these deliveries.

The revised irrigation strategy was evolved by selecting the most favourable tested regime within specific growth stages and combining these in sequence, but there was no supporting evidence that, when applied as a whole, the practice would be beneficial. The application of the revised irrigation practice on the Estate proved successful but experimental verification of this would be useful, particularly with reference to possible long term deleterious effects.

The increased water duty derived as a consequence of the adoption of the revised budget indicates that the potential area of cane can be expanded by 17% using the Estate's normal water supply, assuming a 75% efficiency of water use. Full exploitation of this potential increase, however, may not be advisable as a precaution against future reductions in water reserves and the concomitant abandonment of fields.

The revised irrigation regime resulted in no loss of yield and a reduction in input costs together with the promise of an expansion in the irrigable area. Clearly, in the absence of further evidence to the contrary in the short term, future irrigation practice must remain in favour of the revised strategy.

The irrigation strategy developed in this review relates the physiological development of the crop, and its demand for water in three phases, to climatic and soil variables in Zimbabwe. It is likely that the principles upon which the revised water policy was evolved will apply to other similar sugar producing areas when suitably modified for local environmental conditions.

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APPENDIX I

Drying-off schedules in relation to time of year, predicted evaporation and total available moisture.

			Last date of irrigation (week number) for specified harvest date					
Week No. (a)	Date (b)	Mean Pan Evaporation mm	Total available moisture mm					
			61-70 (c)	71-80 (d)	81-90 (e)	91-100 (f)	101-110 (g)	111-120 (h)
6	05.02 to 11.02	44						
7	12.02 to 18.02	43						
8	19.02 to 25.02	42						
9	26.02 to 04.03	41						
10	05.03 to 11.03	40						
11	12.03 to 18.03	37						
12	19.03 to 25.03	36						
13	26.03 to 01.04	36						
14	02.04 to 08.04	31	9	9	8	7	7	6
15	09.04 to 15.04	33	10	9	8	8	7	6
16	16.04 to 22.04	29	11	10	9	8	8	7
17	23.04 to 29.04	29	12	11	10	9	8	8
18	30.04 to 06.05	29	12	11	11	10	9	8
19	07.05 to 13.05	26	13	12	11	11	10	9
20	14.05 to 20.05	24	14	13	12	11	10	10
21	21.05 to 27.05	23	14	13	13	12	11	10
22	28.05 to 03.06	22	15	14	13	12	12	11
23	04.06 to 10.06	22	16	15	14	13	12	11
24	11.06 to 17.06	22	17	16	15	14	13	12
25	18.06 to 24.06	21	17	16	15	14	13	13
26	25.06 to 01.07	21	18	17	16	15	14	13
27	02.07 to 08.07	22	19	18	17	16	15	14
28	09.07 to 15.07	23	20	19	18	16	15	15
29	16.07 to 22.07	25	21	20	18	17	16	15
30	23.07 to 29.07	26	22	21	19	18	17	16
31	30.07 to 05.08	26	23	22	20	19	18	17
32	06.08 to 12.08	28	24	23	22	20	19	18
33	13.08 to 19.08	31	26	24	23	22	20	19
34	20.08 to 26.08	34	27	26	25	23	22	21
35	27.08 to 02.09	37	29	28	26	25	24	22
36	03.09 to 09.09	37	30	29	28	27	25	24
37	10.09 to 16.09	40	32	31	30	28	27	26
38	17.09 to 23.09	45	34	33	31	30	29	28
39	24.09 to 30.09	46	35	34	33	32	31	30
40	01.10 to 07.10	47	36	35	34	34	33	32
41	08.10 to 14.10	48	37	37	36	35	34	33
42	15.10 to 21.10	49	38	38	37	36	35	35
43	22.10 to 28.10	49	39	39	38	37	37	36
44	29.10 to 04.11	49	40	40	39	38	38	37
45	05.11 to 11.11	49	41	41	40	40	39	38
46	12.11 to 18.11	49	43	42	41	41	40	39
47	19.11 to 25.11	50	44	43	42	42	41	40
48	26.11 to 02.12	50	45	44	43	43	42	41
49	03.12 to 09.12	51	46	45	44	44	43	43
50	10.12 to 16.12	51	47	46	45	45	44	44
51	17.12 to 23.12	48	48	47	46	46	45	45
52	24.12 to 30.12	46	49	48	47	47	46	45

Use of the above schedule is illustrated by the following examples.

Example 1

Determine the last irrigation date for a field with a TAM of 100 mm to be harvested on 30th July. The date of harvest (column b) corresponds to week 31 (column a). Looking across this row to the corresponding TAM column for 100 mm (column f) it can be seen that the last irrigation for this harvest date is given as week 19. Referring again to column a, it can be seen that week 19 is 7-13 May, which is when the last irrigation should occur, ie approximately 80 days before harvest.

Example 2

A shallow sandy field with a TAM of 65 mm is due for harvest at the end of the season during the last few days of November. The harvest period corresponds with week 48 in the Table, and the last irrigation should be given during week 45 (column c for 65 mm TAM) ie approximately 3 weeks before harvest.

APPENDIX II

Estimated monthly irrigation requirements in Zimbabwe Lowveld: Revised scheduling

MONTH	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	TOTAL
Pan evaporation mm	134	114	91	105	139	184	217	213	214	215	164	170	1 960
Effective rainfall mm	14	–	–	–	–	–	12	40	58	65	59	43	291
Nett pan evap. mm	120	114	91	105	139	184	205	173	156	150	105	127	1 669
Pan Factor	HARV	–	–	–	R.I.	0,8	0,8	0,8	0,8	0,8	0,8/DO	DO	
Demand	100	–	–	–	100	147	164	138	125	120	57	–	951
Pan Factor	DO	HARV	–	–	R.I.	0,8	0,8	0,8	0,8	0,8	0,8	0,8/DO	
Demand	–	100	–	–	100	147	164	138	125	120	84	39	1 017
Pan Factor	DO	DO	HARV	–	–	R.I.	0,8	0,8	0,8	0,8	0,8	0,8	
Demand	–	–	100	–	–	100	164	138	125	120	84	102	933
Pan Factor	0.8/DO	DO	DO	HARV	–	–	R.I.	0,8	0,8	0,8	0,8	0,8	
Demand	74	–	–	100	–	–	100	138	125	120	84	102	843
Pan Factor	0.8	0.8/DO	DO	DO	HARV	–	–	R.I.	0,8	0,8	0,8	0,8	
Demand	96	82	–	–	100	–	–	100	125	120	84	102	809
Pan Factor	0.8	0,8	0,8	0,8/DO	DO	HARV	–	–	R.I./0,8	0,8	0,8	0,8	
Demand	96	91	73	24	–	100	–	–	170	120	84	102	860
Pan Factor	0,8	0,8	0,8	0,8	0,8	DO	HARV	–	R.I.	0,8	0,8	0,8	
Demand	120	91	73	84	111	–	100	–	100	120	84	102	985
Pan Factor	0,8	0.8	0.8	0,8	0,8	0,8	DO	HARV	–	R.I.	0,8	0,8	
Demand	120	91	73	84	111	147	–	100	–	100	84	102	1 012
Pan Factor	0,8	0,8	0,8	0,8	0,8	0,8	0,8	DO	HARV	–	R.I.	0,8	
Demand	120	91	73	84	111	147	164	–	100	–	100	102	1 092
Total	726	546	392	376	633	788	856	752	995	940	745	753	8 502
Mean mm/Month	81	61	43	42	70	88	95	83	111	104	83	84	945

HARV = Harvest month
R.I. = Commencement of regular irrigation
DO = Drying off

Pan evaporation 25 year mean
Effective rainfall = 50% mean
Nett crop demand at 100% efficiency = 945 mm
Water duty at 100% efficiency = 3 337 ha/cumec

APPENDIX III

Estimated monthly irrigation requirements in Zimbabwe Lowveld: Conventional scheduling

MONTH	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	TOTAL
Pan evaporation mm	134	114	91	105	139	184	217	213	214	215	164	170	1 960
Effective rainfall mm	14	–	–	–	–	–	12	40	58	65	59	43	291
Nett pan evap. mm	120	114	91	105	139	184	205	173	156	150	105	127	1 669
Et/Eo	HARV	0.45	0.60	0,75	0,90	1,00	1,00	1,00	1,00	1,00	0,80	0,50	
Demand	48	51	55	79	125	184	205	173	156	150	84	64	1 374
Et/Eo	0.50	HARV	0,45	0,60	0,75	0,90	1,00	1,00	1,00	1,00	1,00	0,80	
Demand	60	46	41	63	104	166	205	173	156	150	105	102	1 371
Et/Eo	0,80	0,50	HARV	0,45	0,70	0,85	1,00	1,00	1,00	1,00	1,00	1,00	
Demand	96	57	36	47	97	156	205	173	156	150	105	127	1 405
Et/Eo	1,00	0.80	0.50	HARV	0,50	0,75	1,00	1.00	1,00	1,00	1,00	1,00	
Demand	120	91	46	42	70	138	205	173	156	150	105	127	1 423
Et/Eo	1.00	1.00	1.00	0,50	HARV	0,50	0,75	1,00	1,00	1,00	1,00	1,00	
Demand	120	114	91	53	56	92	154	173	156	150	105	127	1 391
Et/Eo	1.00	1.00	1.00	1,00	0,50	HARV	0,55	0,90	1,00	1,00	1,00	1,00	
Demand	120	114	91	105	70	74	113	156	156	150	105	127	1 381
Et/Eo	1.00	1.00	1.00	1,00	1,00	0,50	HARV	0,55	0,90	1,00	1,00	1,00	
Demand	120	114	91	105	139	92	82	95	140	150	105	127	1 360
Et/Eo	1.00	1,00	1.00	1,00	1,00	1,00	0,50	HARV	0,55	0,90	1,00	1,00	
Demand	120	114	91	105	139	184	103	69	86	135	105	127	1 378
Et/Eo	1.00	1,00	1.00	1,00	1.00	1,00	1,00	0.50	HARV	0,55	0,90	1,00	
Demand	120	114	91	105	139	184	205	87	62	83	95	127	1 412
Total	924	815	633	704	939	1 270	1 477	1 272	1 224	1 268	914	1 055	12 495
Mean mm/Month	103	91	70	78	104	141	164	141	136	141	102	117	1 388

HARV = Harvest month
Harvest month Et/Eo = 0.4

Pan evaporation 25 year mean
Effective rainfall = 50% mean
Nett crop demand at 100% efficiency = 1 388 mm
Water duty at 100% efficiency = 2 272 ha/cumec