SHORT, NON-REFEREED PAPER

SOFTWARE FOR EVALUATING SUGARCANE IRRIGATION STRATEGIES DURING DROUGHT

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Abstract

Irrigation water supply for sugarcane production in South Africa is often limited by drought and managing irrigation under these conditions is complex. A computer program was developed to enable sugarcane farmers to assess the likely impact of their irrigation decisions on crop growth and farm profitability.

The MS Excel program uses a crop and water balance model to calculate the impact of specified irrigation strategies on crop yield and survival under assumed future water allocation and climate scenarios. Farm level gross margins (GM), for three consecutive years (Y1, Y2, Y3) are calculated from simulated yields, cost of irrigation applied and production costs at field level. Irrigation strategies that can be explored include: (1) scheduling rules based on growth phase specific soil water thresholds (SWT) of 60, 30 and 20% of water-holding capacity, (2) reducing irrigation amounts, and (3) abandoning low potential fields. Inputs are entered in simple spreadsheets and results are presented in graphical and tabular forms.

A case study was conducted for a hypothetical farm in Komatipoort with 18 fields, subjected to four restricted water allocation scenarios differing in severity (50 and 25% of the norm) and duration (24 and 12 months). Results show that using SWT of 30 and 60% for the tillering and stalk growth phases respectively, produced the best farm average yield and GM for each of four water allocation scenarios. Although lower SWT enabled the survival of more fields, it led to substantial reductions in yield and GM in Y1 and Y2. Withholding irrigation on fields that were due to die, increased farm GM in Y2 marginally.

Initial results suggest that predictions from the program are realistic, and that it has the potential to aid irrigation decision-making during drought to minimise its negative impacts. Further evaluation under diverse scenarios are recommended.

Keywords: drought, decision support program, irrigation, gross margin, water allocation, water balance, crop model

Introduction

Irrigation water supply for sugarcane production in South Africa is often limited by drought, and managing irrigation under these conditions is complex. Farmers could benefit if they were able to reliably assess the impact of irrigation decisions on future crop growth and farm profitability under these circumstances. The objective of this work was to develop and evaluate a computer program that would facilitate such assessments.

Methods

Program description

The program, coded in Microsoft Excel, uses a sophisticated crop and water balance model to calculate the impact of specified irrigation strategies on crop yield and survival under assumed future water allocation and climate scenarios. Farm level gross margins for the current and next season are calculated from yields, irrigation applied and production costs at field level. Irrigation strategies that can be explored include: (1) scheduling rules based on growth phase specific soil water depletion thresholds; (2) reducing irrigation amounts; (3) adjusting the drying off period; and (4) abandoning low potential fields.

User inputs are organised as farm inputs (weekly water allocation, daily weather data), field inputs (size, crop cycle dates, variety, ratoon stage, soil type, irrigation system type and irrigation strategy) and financial information (production costs and RV price).

The user specifies past and expected future water allocation, and the expected category of future rainfall. The user also defines a field specific irrigation strategy consisting of growth stage specific soil water thresholds (SWT) and survival priority for the current (Y1) and the next season (Y2).

Program output is described in Figure 1.

Case study

A hypothetical farm, situated near Komatipoort, consisting of 18 fields of one hectare each, was set up in the program. Sixteen of these fields had cane growing on them, with ratoon stages varying from a plant crop through to the 7th ratoon. Crops were harvested (and started) on the 15th of each month of the milling season (April to December). Two fallow fields from Y1 were planted in Y2, while the two oldest ratoons from Y1 were ploughed out and fallowed in Y2. Fields had identical soils with available water capacity of 100 mm. Overhead irrigation with a typical application of 35 mm and a minimum cycle of 5 days were assumed. The 'pro rata' rule developed by Paraskevopoulos (2016) was used to limit per field cumulative irrigation to not exceed the corresponding cumulative water allocation. Soil profiles were filled to capacity after harvest, when water was available, and water was withheld during the specified drying off period. Weather data from the Tenbosch station near Komatipoort for the period from April 2014 to December 2016 (an extremely dry period) were used for the simulations. Financial information for 2017 were used in GM calculations.

Four restricted water allocation scenarios were simulated, namely 50 and 25% of the normal allocation, for the periods from January 2015 to December 2016 (long drought), and from January 2016 to December 2016 (short drought). Weekly allocations were determined using the estimated long term mean weekly irrigation demand and the level of restriction.

Irrigation strategies included using SWT of 60%, 30% and 20% of the available soil water capacity for the tillering and stalk growth phases (fields received full irrigation during the germination phase). Ceasing irrigation on selected fields (abandonment) at the start of the period of restricted water allocation were also investigated.

SWOP results for: Komati _WA600mm_SWT30-60 Run date: 2018/03/15

Field name	Field size 2015	Field size 2016	Ratoon # 2015	Ratoon # 2016	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15
1	1	1	0	1	37	35	0	0	0	105	105	70	70	70
2	1	1	0	1	1	100	0	0	0	105	70	105	70	70
3	1	1	1	2		68	0	0	0	105	105	105	35	70
4	1	1	1	2		36	35	0	0	105	105	105	35	84
5	1	1	2	3			70	0	0	35	105	70	70	70
6	1	1	2	3			70	0	0	35	105	70	70	70
7	1	1	3	4				70	0	0	105	105	35	50
8	1	1	3	4				70	0	0	105	105	35	21
9	1	1	4	5					70	0	35	105	35	0
10	1	1	4	5					70	0	35	105	35	0
11	1	1	5	6						105	0	70	35	0
12	1	1	5	6						105	0	49	35	0
13	1	1	6	7							70	0	70	0
14	1	1	6	7							70	0	58	0
15	1	1	7	-1								35	35	0
16	1	1	7	-1								35	35	0
17	1	1	-1	0										
18	1	1	-1	0										
Rainfall (mm):					38	0	0	0	12	1	48	65	302	47
Water applied (mm):					50	79	51	55	48	78	85	71	33	24
Water allocated (mm):					55	85	64	93	105	137	170	103	115	57

Field name	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
1	140	0	0	97	0	0	105	105	70	70	70	70	70	0	0								
2	140	0	0	60	35	0	105	105	70	70	70	70	70	0	0								
3	140	70	0	0	86	0	0	140	105	70	35	105	35	70	0	0							
4	108	70	0	0	80	0	0	105	140	70	35	105	35	70	0	0							
5	107	105	35	0	70	0	0	0	140	70	105	70	70	70	70	0	0						
6	94	105	70	0	37	35	0	35	140	64	91	70	70	70	35	0	0						
7	17	134	140	35	0	70	0	0	76	105	89	105	35	70	70	28	0	0					
8	0	144	105	70	0	70	0	0	70	59	105	91	59	70	81	35	0	0					
9	0	117	82	105	70	0	70	35	9	35	47	64	21	67	79	105	93	0	0				
10	0	56	95	70	70	0	70	35	0	35	35	0	35	35	15	112	70	0	0				
11	0	0	32	93	70	105	35	105	0	0	35	0	35	29	0	87	85	70	35	0			
12	0	0	0	0	0	0	0	0															
13	0	0	0	0	0	0	0	0	0														
14	0	0	0	0	0	0	0	0	0														
15	0	0	0	0	0	0	0	0	0	0													
16	0	0	0	0	0	0	0	0	0	0													
17											70	0	0	105	105	35	35	35	70	70	94	18	0
18											70	0	0	105	105	35	35	35	70	70	58	0	0
Rainfall (mm):	3	38	9	0	7	5	2	5	6	137	93	37	94	42	3	12	8	4	32	0	26	152	89
Water applied (mm):	40	45	29	29	29	12	18	34	46	43	65	56	43	57	41	37	36	29	44	74	63	43	55
Water allocated (mm):	49	41	44	31	29	43	49	63	79	48	63	47	49	52	34	31	36	36	49	80	61	48	63

Field name	2015 Crop status	2015 Irrigation(mm)	2015 Cane yield (t/ha)	2015 Gross margin (R1000/ha)	2016 Crop status	2016 Irrigation(mm)	2016 Cane yield (t/ha)	2016 Gross margin (R1000/ha)	2015/01/15 Soil water (mm)	2015/01/15 Canopy (%)
1	Alive	632	92	36	Alive	657	108	48	88	99
2	Alive	661	91	35	Alive	655	108	49	88	99
3	Alive	698	113	72	Alive	646	102	60	88	99
4	Alive	682	109	69	Alive	640	102	60	67	99
5	Alive	667	104	68	Alive	665	103	66	53	98
6	Alive	689	106	70	Alive	648	98	62	53	98
7	Alive	691	102	67	Alive	647	94	61	53	98
8	Alive	655	97	62	Alive	640	96	63	53	98
9	Alive	619	90	53	Alive	625	90	53	53	98
10	Alive	536	80	41	Alive	441	72	30	53	98
11	Alive	544	71	25	Alive	481	74	31	54	97
12	Dead	189	29	-19	Dead	0	0	-16	54	97
13	Dead	140	15	-18	Dead	0	0	-15	55	94
14	Dead	128	14	-18	Dead	0	0	-15	55	94
15	Dead	70	0	-16	Fallow	0	0	0	60	86
16	Dead	70	0	-16	Fallow	0	0	0	60	86
17	Fallow	0	0	0	Alive	637	98	26	0	0
18	Fallow	0	0	0	Alive	583	93	23	0	0
Total	11	479	69	32	13	498	78	37	66	85

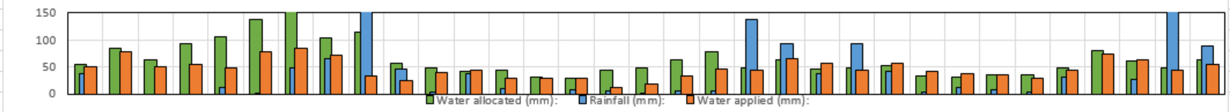

Figure 1. Output summary sheet showing monthly simulated irrigation amounts (mm) applied by the model on each field, for the past (green) and future (pink) period. The water balance graph at the bottom shows monthly rainfall, water allocation and irrigation applied on the farm. On the right the simulated crop status, cane yield, and gross margin at field and farm level for the two seasons are shown. The simulated soil water content and canopy cover on the current date are shown on the far right, to inform the user of model accuracy for possible resetting with observed data.

Results and Discussion

Results show that using SWTs of 30 and 60% for the tillering and stalk growth phases respectively, produced the best farm average yield and GM for each of four water allocation scenarios (Table 1). Withholding irrigation on fields that were due to die, increased farm GM in Y2 marginally, because saved water could be redirected to high potential fields. Using a SWT of 30% throughout succeeded in saving more fields, thus ensuring higher future production capacity, but it also caused a reduction in yield and GM for Y1 and Y2 (Table 1).

Other findings include:

- Using a SWT of 20% is not a realistic strategy under any circumstance as it causes excessive crop damage and yield losses (results not shown).
- Extending the drying off period should only be considered for mildly restricted allocations (>50%). Extending drying off during severe water restrictions (<50%) can lead to unwanted crop death (results not shown).

Table 1. Simulation results for year one, two and three (Y1, Y2, Y3) for different irrigation strategies employed under different water allocation regimes for a hypothetical farm.

Water Allocation (mm/year)	Irrigation Strategy			Irrigation Amount (mm)		Crop Survival (# fields)		Cane yield (t/ha)		Gross Margin (R1000/ha)		
	SWT[1] Tillering	SWT Stalk	Fields Abandoned	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2	Y3
1300	60+	60	0	698	996	16	16	110	120	56	71	44
Long drought (24 months)												
600	60	60	0	577	488	16	11	98	94	46	28	30
600	30	60	0	577	550	16	12	98	91	46	29	33
600	30	30	0	435	437	16	15	83	67	34	15	41
600	30	60	4	577	590	16	11	98	94	46	31	30
300	60	60	0	445	292	16	10	83	57	33	-4	27
300	30	60	0	445	292	16	10	83	57	33	-4	27
300	30	30	0	383	271	16	13	77	49	27	-6	35
300	30	60	6	445	349	16	9	83	59	33	2	25
Short drought (12 months)												
600	60	60	0	698	678	16	13	110	105	56	44	35
600	30	60	0	698	681	16	13	110	106	56	44	35
600	30	30	0	698	651	16	15	110	93	56	43	41
600	30	60	3	698	792	16	13	110	106	56	47	35
300	60	60	0	698	542	16	12	110	91	56	28	33
300	30	60	0	698	542	16	12	110	92	56	28	33
300	30	30	0	698	535	16	13	110	86	56	27	35
300	30	60	4	698	659	16	12	110	92	56	32	33

[1] SWT- soil water threshold (% of available soil water capacity, also known as TAM)

Conclusion

A MS Excel program was developed for predicting the impact of irrigation strategies on crop status and gross margins at field and farm level. Initial results suggest that predictions are realistic, and that it could aid strategic irrigation decision-making during drought to minimise its negative impacts. Further evaluation under diverse scenarios are recommended.

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