PREDICTING THE IRRIGATION POTENTIAL OF A SMALL CATCHMENT FROM RUNOFF SIMULATIONS AND METEOROLOGICAL DATA WITH THE COMPUTER MODEL "DAM FULL"

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Abstract

"Dam Full", a computer model for assessing the irrigation potential of a farm-scale catchment, is described. The use of the model as the starting point of an economic feasibility study for building a dam for irrigation is explained. Possible future developments are suggested and ways of increasing its accuracy are also discussed.

Introduction

The irrigation of sugarcane in South Africa often involves the damming of natural streams to provide water. Assessing the suitability of these watercourses, in terms of their catchment areas and anticipated runoff yield, as well as matching the estimated monthly requirements for irrigation water with the required size of a dam, necessitates lengthy and repetitive calculations. The complexity of the exercise led to the consideration of developing a suitable computer model for this task.

Initially, the simplicity of the "Visi Calc" spread sheet was attractive, but because input of the data is an onerous task, it was decided that a menu-type programme might be more appropriate.

Description of the model

The structure of the model is shown in Figure 1.

Irrigation water requirements

The net water requirements for irrigating sugarcane in a particular locality are calculated on a monthly basis from climatic data available from local weather stations and from soil data obtained from on-site inspections of soil profiles (Cross[1]).

Available water storage and supply

In the model, the simulated runoff for tertiary (farm-scale) catchments is used to calculate runoff from a mapped catchment area, the sediment yield maps are used to determine a

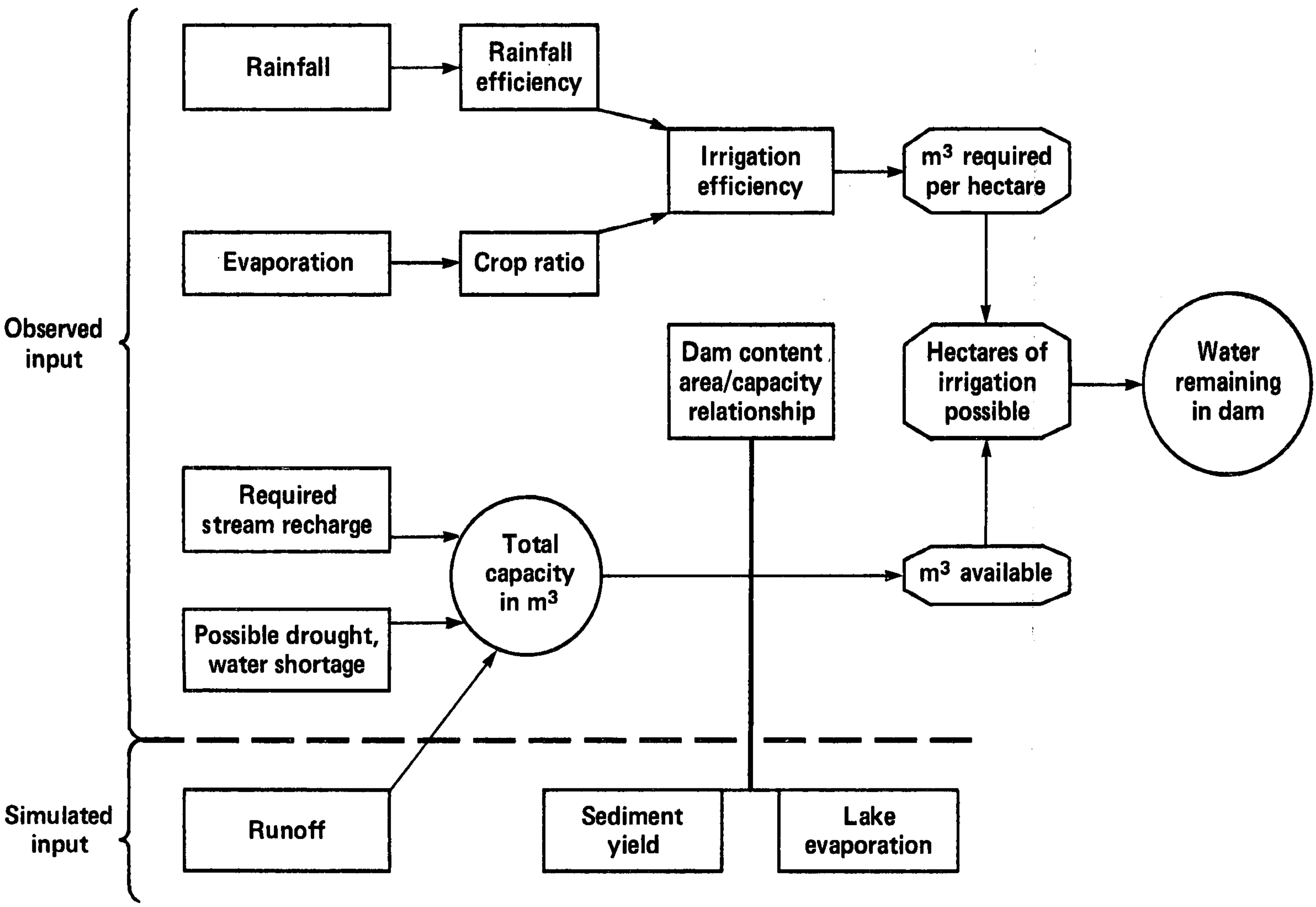

FIGURE 1 The different elements considered in the "Dam Full" model.

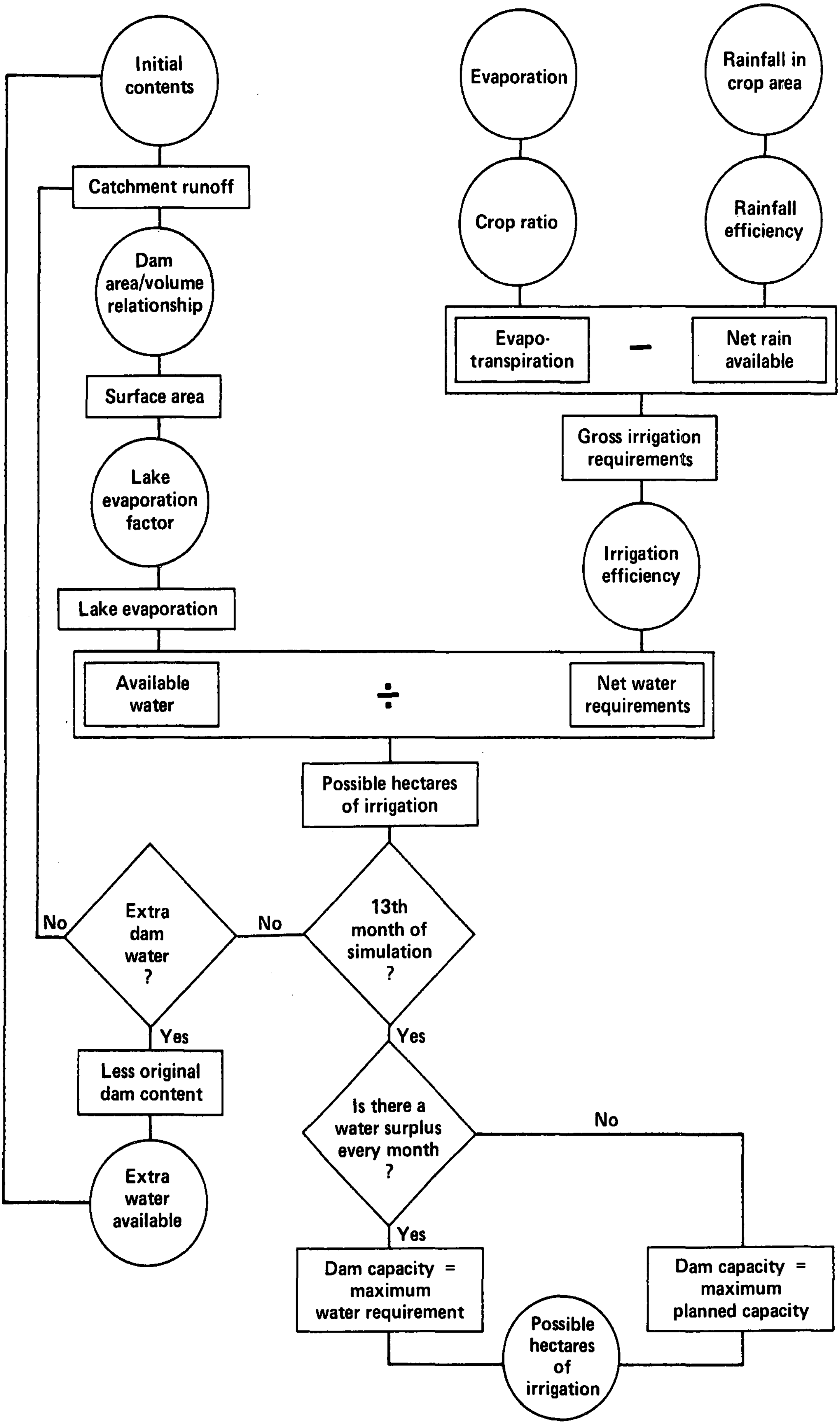

FIGURE 2 Flow chart of "Dam Full" programme.

sediment deposit allowance and the universal evaporation loss diagram is used to determine evaporation losses from the proposed dam. These data are simulated from gauged stream flows, evaporation and rainfall records (Pitman *et al*[2]).

Optional sizes and capacities of the proposed dam are calculated from orthophotographic maps of the farm and the dam site or from a survey of the dam site.

Computer aspects

The program is written in Basic and allows easy access for future development and alteration. It is designed for the Hewlett Packard HP 85 microcomputer fitted with a 16 K RAM. The program requires 14 kilobytes to run. All data are predimensioned to tabulate results and inputs on the printout, which is not complicated and which is self-explanatory (Appendix 1).

The operation of the "Dam Full" program

The flowchart of the program is shown in Figure 2.

After calculating the available runoff by taking into account the total runoff, stream re-charge and water shortage due to drought, the program updates the water available for irrigation on a monthly basis by sequentially adding the available runoff to the initial dam content and then subtracting the volume occupied by sediment and water lost through lake evaporation.

The area that could possibly be irrigated is then calculated, taking into account the monthly requirement of the crop which is computed from crop ratio and climatic inputs. This possible area is "irrigated" by the computer within an upper limit determined by the farmer or operator. Any water remaining in the dam after this function, is carried over to the next month's simulation.

The program includes the option of simulating another year or other years, or modifying data after the results sheet is printed (Appendix 1).

Calculated Example

In this example, a particular farm in the Seven Oaks area was selected and actual data are used. The worksheet contains the observed and simulated data for the farm and area (Appendix 2).

Step 1

- The dam's catchment area is measured and located on the relevant tertiary catchments boundary map. Details of the runoff and sediment yield from the catchment are entered.
- Rainfall and evaporation data from the Seven Oaks meteorological station are used, and an average crop factor for the proposed area to be irrigated, is calculated and entered.
- Stream re-charge and water shortage as a result of drought is estimated and entered.
- The capacity of the proposed dam is calculated by the prismoidal formula after the areas of the contours of the dam basin have been measured by planimeter on a 1:6 000 scale orthophoto of the farm. The capacity is then entered.

Data from the worksheet are fed into the computer as they are requested by the program (Appendix 2).

Step 2

The results sheet should be evaluated before terminating the program. In the example, a dam with a proposed capacity of 159 750 cubic metres is excessive for average conditions; for the area to be irrigated, the maximum capacity required is 135 567 cubic metres.

The displayed "Do you want to modify? (Y/N)" query allows any item of data to be adjusted. A larger irrigated area can be input and/or the dam data can be adjusted to arrive at the final acceptable dam/irrigated area relationship.

Step 3

After modification or simulation of another year, or other years, the new results are printed with further options to modify data, simulate other years, or to end the run.

Discussion

Although the "Dam Full" program provides the opportunity of exploring the interactions between the various input parameters because it allows any of the data to be modified, the shortcomings of the model stem from assumptions made in the derivation of the basic data used.

For example, a better knowledge of the relationship between drought and runoff is required. In the model it is assumed that runoff is proportional to rainfall, ie rainfall efficiency does not decline as the amount of rain and therefore the likelihood of runoff increases.

The required storage capacity is accurately calculated in the model from monthly runoff simulation when dam sites are being considered. However, when a small weir type structure is planned to obtain the storage, or when the catchment yield exceeds the irrigation requirement or storage balance, stream flow data as additional data, would make the calculations more accurate.

By simulating irrigation for several years, the characteristics of the required storage capacity can be noted and decisions can be made on the size of the dam, the area that can be irrigated in years of drought, and even the irrigation regime and the harvesting program.

Conclusion

The "Dam Full" program offers those with limited knowledge of computers the oportunity of determining fairly accurately, and within a matter of hours, the irrigation requirement or water storage.

Acknowledgements

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REFERENCES

1. Cross, KW (1984). Irrigation design criteria for sugarcane. *Proc S Afr Sug Technol Ass* 58: 133-136.
2. Pitman, WV, Middleton, BJ and Midgley, DC (1981). *Surface water resources of South Africa*. Report No 9/81 Hydrological Research Unit, University of the Witwatersrand.

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"DAM FULL" DATA WORKSHEET

FARM NAME: EXAMPLE

TERTIARY CATCHMENT: NAME: U40

AREA: 3155 km2

MEAN ANNUAL RUNOFF: 537,22 E6m3

FARM CATCHMENT AREA: 8,36 km2

PLANNED CROP: NCo 376

PLANNED IRRIGATED AREA: 100 ha

AVERAGE MONTHLY DATA

	Mean monthly runoff %	Mean monthly evaporation Eo mm	Crop ratio	Mean monthly rainfall mm	Rain efficiency	PAN factor
JAN	14,33	173,6	0,9	159	0,65	1
FEB	10,91	159,5	0,95	122	0,70	1
MAR	15,69	155	1	124	0,70	1
APR	9,94	126	1	57	0,80	1
MAY	5,4	111,6	0,75	35	0,80	1
JUN	3,86	105	0,30	8	0,95	1
JUL	2,75	114,7	0,10	13	0,95	0,8
AUG	2,85	142	0,25	33	0,85	0,8
SEP	3,05	156	0,35	65	0,80	0,8
OCT	5,26	176,7	0,45	95	0,80	0,8
NOV	8,66	165	0,65	112	0,70	1
DEC	17,30	182,9	0,85	123	0,70	1

IRRIGATION EFFICIENCY: 80 % PART OF THE RUNOFF AVAILABLE: 90 % INITIAL MONTH: SEPT

DROUGHT COEFFICIENT: 0 %

DAM DATA: INITIAL CONTENT: 0 m^3 INITIAL AREA: 0 m^2

Step	Content m^3	Area m^2
1	20	200
2	1 450	1 430
3	4 090	2 640
4	8 360	4 270
5	14 250	5 890
6	21 750	7 500
7	34 750	13 000
8	54 750	20 000
9	81 750	27 000
10	115 750	34 000
11	159 750	44 000
12	0	
13		
14		
15		

SILT DEPOSIT: 150 T/km2/annum

DAM oo FULL

FARM NAME : EXAMPLE		PLANNED CROP	: NCO 376
TERTIARY CATCHMENT : U40	AREA : 3155.00 km2	PLANNED IRRIGATED AREA	: 100 ha
MEAN ANNUAL RUNOFF : 357.22 E6m3		PART OF THE RUNOFF AVAILABLE	: 90 %
EXAMPLE FARM CATCHMENT,	AREA : 8.36 km2	INITIAL MONTH OF SIMULATION	: 7
MEAN ANNUAL RUNOFF : .95 E6m3		DROUGHT WATER SHORTAGE	: 0 %
SILT DEPOSIT : 150 T/km2/annum	PROVISION SILT 20 YEARS : 4444 m3	IRRIGATION EFFICIENCY	: 80 %

AVERAGE MONTHLY DATA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOT
MEAN MONTHLY RUNOFF %	14.30	10.90	15.70	9.90	5.40	3.90	2.80	2.80	3.10	5.30	8.70	17.30	100.10
MEAN MONTH RUNOFF m3	135356	103174	148608	93708	51114	36915	26503	26503	29343	50167	82350	163753	947495
MEAN MONTH EVAP Eo mm	173.60	159.50	155.00	126.00	111.60	105.00	114.70	142.00	156.00	176.70	165.00	182.30	1767.40
MEAN MONTH RAIN mm	159.00	122.00	124.00	57.00	35.00	8.00	13.00	33.00	65.00	95.00	115.00	123.00	949.00
RAIN EFFICIENCY	.65	.70	.70	.80	.80	.95	.95	.85	.80	.80	.70	.70	
CROP RATIO	.90	.95	1.00	1.00	.25	.30	.10	.25	.35	.45	.65	.85	
MEAN MONTH EVAP Et mm	156.24	151.53	155.00	126.00	27.90	31.50	11.47	35.50	54.60	79.52	107.25	154.96	1091.46
EFFECTIVE RAIN mm	103.35	85.40	86.80	45.60	28.00	7.60	12.35	28.05	52.00	76.00	80.50	86.10	691.75
IRRIGATION NEEDED mm	66.11	82.66	85.25	100.50	0.00	29.88	0.00	9.31	3.25	4.39	33.44	86.07	500.86
PAN FACTOR	1.00	1.00	1.00	1.00	1.00	1.00	.80	.80	.80	.80	1.00	1.00	

MAX CAPACITY NEEDED m3	POSSIBLE IRRIGATED AREA ha 0 % WATER SHORTAGE CONDITIONS												YEAR
135567	100	100	100	100	100	100	100	100	100	100	100	100	1

COMMENTS