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An Appraisal of Water and Power Budgeting Systems for Sustainable Irrigation at Ubombo

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Abstract

An analysis is given of the water and power budgeting systems used at Ubombo Sugar estate for sustainable irrigation water supply. A desk review of the approaches used to establish water and power budgets was carried and a new model was developed parallel to existing budgets to establish discrepancies. The development process constituted a broad set of parameters such as meteorological data, crop data and planted area, harvesting programs, irrigation systems, pumps and motor specifications, pumping hours, cost per kilowatt hour and actual flow rates. Water and power budgets were found not satisfactory with regards to satisfying crop water demand. Actual water inflows and pumping were determined by capacities of structures used for conveyance and losses were incurred during periods of low demand due to continuous flow type of delivery system. Electricity budgets were often based on historical power records which affected overall water supply as 70% of the estate is under pressurized irrigation. The new model developed from first principles of water and power demand demonstrated that existing budgeting systems limited the use of the resources particularly electricity and caused severe losses on irrigation water. Inaccurate supply-demand indices also affected decision making on bulk water management. Consequently, a new and improved budgeting model needs to be developed and adopted for sustainable irrigation water supply and sugarcane yields.

Keywords: Budget, irrigation, power, sugarcane, water supply, Ubombo.

Introduction

Ubombo Sugar estate depends heavily on irrigation for sustainable sugarcane production as annual rainfall meets approximately 50% of crop water demand. Bulk water sources are also increasingly becoming unreliable due to erratic rains and by virtue of the estate being at the downstream of all irrigation schemes in the Usutu River Basin. Extreme pressure is normally experienced during peak demand when the crop evapotranspiration is generally high which often coincides with periods of low rainfall and the common practice is for upstream farmers to abstract more water at the expense of the tail enders. On the other hand, impetus for strategic developments such as expansion of area under sugarcane and conversion of conventional irrigation methods is still on. These challenges prompts for a review of the bulk water management systems normally used to establish sustainable water management systems that will meet crop water needs, minimize water losses and energy costs and cope with prevalent unpredictable weather patterns. Irrigation water management has become an urgent issue in irrigated agricultural sectors worldwide to increase irrigation water use efficiency[1]. Water shortages increase rapidly as industrial and agricultural needs rise in line with socio-economic development, population growth and poor water management[2,3,4]. Improper irrigation water management practices cause not only wastage of water but a significant reduction in crop yield, quality and water use efficiency[5]. Bulk water management helps in guiding the application of water; to meet crop needs, in ensuring the correct amount is held in the soil and made available to crop[6]. However, some studies reported that irrigation water management is rarely practised in large-scale farming thus neglecting large quantities of water for irrigation[7].

Proper management of irrigation water prevent irrigation induced problems such as waterlogging through application of water in amounts that can be held by the soil and crop and salinization[8]. Soil salinity results when the evapotranspiration rate is higher than precipitation and therefore makes it difficult for plants to uptake water. The amount of water the sugar cane needs, its consumptive use, is equal to the quantity of water lost through evapotranspiration[9]. The water budget is a tool that can be used to assists irrigation decision makers in applying proper irrigation water management taking into account of the crop type, area reference evapotranspiration, precipitation and irrigation system design[10]. The water budget reflects balances between the input and the output of water to and from the root zone taking cognisant of the efficiency of systems and structures used to apply water, hence proper irrigation management is required for efficient and profitable use of water for irrigating agricultural crops. A major part of any irrigation management program is the decision-making process for determining timing for irrigation and or how much water should be applied to the field for each irrigation and this can be achieved through water budgeting techniques. Therefore, it is essential to develop bulk water management strategies to utilize water resources efficiently and effectively[11].

Since about 70% of the estate net area is under pressurized irrigation systems, most of the water requires maximum lifting to effectively command the different areas. Electricity becomes a limiting factor as pumping costs tend to be exorbitant particularly during peak demand and hit hard on budgets. The tendency is to then limit power allocation through telemetry system (ACES) which eventually induces water stress to the crop. The annual power budgets have over the years been developed through historical power records which had some limitations as it failed to accurately capture additional power requirements as a result of expansions and conversions of furrow systems to centre pivot and semi solid set sprinkler systems in the recent years. Development of a new budgeting model for water and power could improve the challenges of water supply and distribution, power allocation and management. Evaluating the existing budgeting systems utilized could form basis for suggesting any improvements in the systems hence the purpose of the review. The assessment constituted analysis of meteorological data to determine crop water and irrigation requirements, net planted area and harvesting program, types of irrigation systems, capacities of pumps and motors, pumping hours, electricity costs, actual water abstractions and water distribution practices. The data was solicited to allow for the development of a water budget from first principles of crop water demand as a function of command area, pumping hours and the cost of pumping water on an annual basis to ultimately develop an accurate power budget. This could improve the performance of irrigation systems and sugarcane yields within the estate.

Material and Methods

Description of study area: Ubombo Sugar estate is situated in Big Bend in the south - east of Swaziland on longitude 32˚52` east and latitude 26˚45`south with an average altitude of 106 m above mean sea level. The estate has a net planted area of about 11, 200 ha under sugarcane for sugar production. It is divided both spatially and administratively into three areas; North, Central and South and each varies according to the number and size of sections contained. Meteorological data is obtained from three weather stations each located in one of the areas. The rainfall regime is unimodal with mean annual rainfall of about 600 mm which normally occurs during summer between October and March. Mean annual temperature is 21^0C and peaks to 39^0C in summer[12]. Water supply for irrigation is from the Great Usutu River through a main gravity canal approximately 39 km long which then subdivides into two primary canals to command the different areas. Ubombo Sugar estate is essentially the downstream user with the largest demand in the consortium after two other commercial irrigation schemes. Major balancing dams, the Van Eck and Sivunga Dam with net storage capacities of 10.4 x 10^6 m^3 and 6.9 x 10^6 m^3 respectively along with night storages of various capacities effectively command the entire estate. Filling of Van Eck Dam and a couple of night storages is achieved by pumping through a number of pumping plants from the primary canals while the Sivunga Dam and other reservoirs are primarily supplied through gravity owing to their spatial location. Irrigation systems comprise 106 centre pivot machines with average size of 50 ha, semi solid set in the outfall of the pivots, conventional sprinkler and furrow irrigation to some extent.

Appraisal of water and power budgeting systems: Parameters appraised included meteorological data to determine crop water and irrigation requirements, area under sugarcane by individual blocks and harvesting program for 2013/14 cropping season, irrigation system type, capacities of pumps and motors, pumping hours, electricity costs, actual water abstractions and distribution practices. As a basis for analysis, a 23 year (1991 – 2013) time series data for radiation, wind speed, relative humidity, rainfall, minimum and maximum temperatures from Ngogo Meteorological station were analysed using Instat software and validated by ETo calculator software to determine the reference evapotranspiration (ETo) for the estate. Canopy factors for sugarcane were integrated with rainfall data to determine sugarcane water and irrigation requirements. The area planted under sugarcane was obtained through composite blocks contained by sections. Harvesting program for the period was used to determine the harvest dates for individual blocks to enable determination of water requirements for the different blocks as influenced by cutting dates. Irrigation systems were studied for the different blocks to establish their efficiencies in terms of water supply. Pump flow rates and motor sizes were also used to determine the maximum hours required to adequately meet crop water demand and power used.

The water and power budget model was developed on Microsoft Excel spread sheet taking into account the ETo, rainfall, canopy factors for sugarcane, empirical efficiencies of irrigation systems per block (sprinklers efficiency-75%, centre pivots- 85% and furrow- 60%)[13]. Net crop water demand was calculated in line with harvest dates of the individual blocks. The irrigation requirement for all cane included the demand for mill cane and seed cane, water supply required excluding losses (gross ML/ha), losses as a function of irrigation system efficiency and total supply required. The annual power usage for all operating pumps was calculated in line with the cost of a kilowatt hour for 2013/14 to determine an annual power budget for the estate. Actual water supply versus crop demand was assessed to determine if the current water management system adequately meets sugarcane water requirements through analysis of monthly water reports for the season. The resultant water and power requirements were then compared with previous budgets to determine their effectiveness of in terms of adequacy of irrigation water supply.

Results and Discussion

Tables 1 – 3 present results of the determination of sugarcane water and irrigation requirements at Ubombo Sugar estate. The output from Instat and ETo calculator programs showed no significant differences in the reference evapotranspiration (ETo). The maximum ETo at peak demand was found to be approximately 6 mm/day (figure-1). Annual ETc was 1167 mm with 461 mm of effective rainfall (table-3). The irrigation requirement for sugarcane is 7 ML/ha which must be applied effectively over the entire period of the growing season. Irrigation systems were found to be satisfactory in applying the target amount as they ranged between 6.5 and 7.1 ML/ha (table-4). The water budgeting model indicates that there are major limitations in the approaches used for agricultural water budgeting at Ubombo. River abstractions are normally determined by capacities of intake structures and during periods of low demand, water is stored in major balancing dams while the rest flows by continuous flow into primary canals and back to natural streams. This approach demonstrates that water inflow into the estate is limited by capacities of abstraction and conveyance structures and little effort is done to determine if part of the abstracted water is effectively supplied into the crop. An equivalent observation was made where improper estimation of canal discharges caused extensive damage to crop yields and loss of life in India[14]. Development of a water budget model from first principles of crop water demand as a function of command area and pumping requirements enabled estimation of actual seasonal water requirements and the power required to lift the water.

The demand, as influenced by dry off periods and harvesting dates were determined with corresponding power requirements to calculate the annual power budgets (tables-4 to 6). Analysis of actual water inflows against crop water demand also demonstrated to have some shortfalls as supply-demand indices were over 100% as a result of inaccuracies in the methodologies used (figure-2). Tail water was often incorporated as supply and the absence of water measuring structures for domestic water abstracted from the bulk water system resulted into higher water supplies than it is for actual irrigation and these results tend to mislead decisions on bulk water management. The ideal approach could be to deduct this portion of water from total estate inflows since the demand factor in the model is only for sugarcane and not for other uses. The total annual water budget for the estate appeared to be slightly higher than the total actual water supply and this prompts for stringent and innovative water management strategies to effectively command the different areas. Power budgeting was also discovered to be based on historical records with some inflation added each year. The major irrigation systems conversions and expansion of area under sugarcane were not factored in the models hence a major difference between current power budgets and the new model developed from first principles. Consequently, the new model could be used as a basis for future budgeting of both water and power as it relatively captures all parameters needed to effectively decide on future water and power requirements for sustainable water supply for irrigation within the estate.

Table-1
Average weather parameters from 1991-2013 for Ngogo Meteorological station

	Apr	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Max ^{0}C	29.4	27.8	25.8	25.7	27.5	29.4	29.2	30.9	32.0	32.6	32.5	31.4
Min ^{0}C	16.9	12.5	8.5	8.4	11.2	15.1	17.6	19.4	20.6	21.3	21.2	20.1
RH Max %	88.8	91.6	91.8	90.3	85.0	78.4	74.4	75.5	77.5	82.0	83.2	85.2
RH Min %	53.1	48.7	46.2	44.0	41.8	45.0	53.4	54.5	55.9	58.0	56.2	56.2
Radiation (MJ/Kg)	16.5	13.7	12.1	12.9	15.5	17.9	18.6	20.7	21.7	23.0	22.1	19.5
Wind Speed (km/day)	63.4	53.9	53.1	64.7	88.8	111.3	112.8	109.5	101.1	92.0	86.4	74.6
Rainfall (mm)	43.2	16.9	11.5	9.9	17.4	23.9	60.5	97.3	104.7	99.9	84.3	70.7

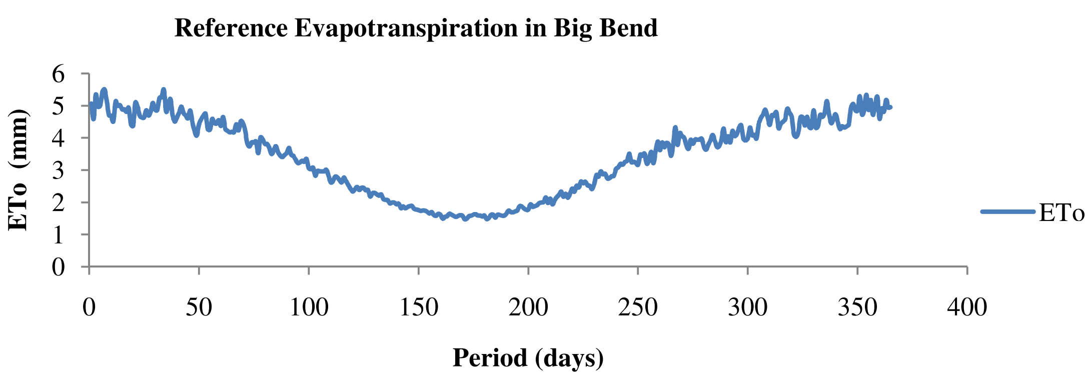

Figure-1
Reference evapotranspiration (ETo) for Big Bend

Table-2
Canopy factors (ETcane / ETo) for cane harvested in different months in Swaziland.

Harvest	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**
Apr	0.4	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May		0.4	0.4	0.4	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.0
Jun			0.4	0.4	0.4	0.5	0.8	1.0	1.0	1.0	1.0	1.0
Jul				0.4	0.4	0.4	0.7	1.0	1.0	1.0	1.0	1.0
Aug					0.4	0.4	0.6	0.9	1.0	1.0	1.0	1.0
Sept						0.4	0.4	0.7	1.0	1.0	1.0	1.0
Oct							0.4	0.4	0.8	1.0	1.0	1.0
Nov								0.4	0.5	0.8	1.0	1.0
Dec									0.4	0.5	0.8	1.0

Table-3
Sugarcane water and irrigation requirements in Big Bend

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
ETo	156	134	158	91	69	53	63	90	116	128	141	107	1306
c/f	1.0	1.0	1.0	0.4	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	
ETc	156	134	158	36	28	32	50	81	116	128	141	107	1167
R	99.9	84.3	70.7	43.2	16.9	11.5	9.9	17.4	23.9	60.5	97.3	104.7	640
Re	80	67	42	26	10	7	6	10	14	36	78	84	461
IRR	76	67	116	11	18	25	44	70	102	91	63	23	706

*ETo = reference evapotranspiration (mm/month) c/f = canopy factor, ETc = cane evapotranspiration (mm/month), R = rainfall (mm), Re = effective rainfall (mm), IRR = irrigation requirement (mm)

Table-4
Water and power budget for Mamba 2 and 3 centre pivots extracted from composite model
Water Requirements FOR 1st APRIL 2013 - 31st March 2014
Ubombo Water Requirements & Crop Factors

	APR	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**TOTAL**
ETo	91	69	53	63	90	116	128	141	107	156	134	158	1306
Gross Rainfall	43	17	12	10	17	24	61	97	105	100	84	71	640
Effecive Rainfall	26	10	7	6	10	14	36	78	84	80	67	42	461
1. APRIL CUT - c/f	0.4	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10
mm	75	18	25	44	70	102	91	63	23	76	67	0	654
2. MAY CUT - c/f	1.0	0.4	0.4	0.4	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.0	10
mm	0	75	14	19	35	79	91	63	23	76	67	116	658
3 JUNE CUT - c/f	1.0	1.0	0.4	0.4	0.4	0.5	0.8	1.0	1.0	1.0	1.0	1.0	10
mm	65	0	75	19	26	44	66	63	23	76	67	116	639
4. JULY CUT - c/f	1.0	1.0	1.0	0.4	0.4	0.4	0.7	1.0	1.0	1.0	1.0	1.0	10
mm	65	59	0	75	26	32	53	63	23	76	67	116	654
5. AUGUST CUT - c/f	1.0	1.0	1.0	1.0	0.4	0.4	0.6	0.9	1.0	1.0	1.0	1.0	10
mm	65	59	46	0	75	32	40	49	23	76	67	116	648
6. SEPTEMBER CUT - c/f	1.0	1.0	1.0	1.0	1.0	0.4	0.4	0.7	1.0	1.0	1.0	1.0	11
mm	65	59	46	57	0	75	15	21	23	76	67	116	619
7. OCTOBER CUT - c/f	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0.4	0.8	1.0	1.0	1.0	11
mm	65	59	46	57	79	0	75	21	1	76	67	116	620
8. NOVEMBER CUT - c/f	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0.5	0.8	1.0	1.0	11
mm	65	59	46	57	79	102	0	75	30	45	67	116	681
9. DECEMBER CUT- c/f	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0.5	0.8	1.0	11
mm	65	59	46	57	79	102	91	0	75	2	40	116	729
Total mm	531	446	344	386	469	567	524	375	183	573	576	927	5903
Mean mm	59	50	38	43	52	63	58	42	20	64	64	103	656
Net crop water demand	**656**												
Application/Ha (mm)	**656**												

USL Water Requirements & Crop Factors

	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
ETo	91	69	53	63	90	116	128	141	107	156	134	158	1306
Gross Rainfall	43	17	12	10	17	24	61	97	105	100	84	71	640
Effecive Rainfall	26	10	7	6	10	14	36	78	84	80	67	42	461
1. APRIL CUT - c/f	0.4	0.4	0.6	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	10
Mm	75	18	25	44	70	102	91	63	23	76	67	0	654
2. MAY CUT - c/f	1.0	0.4	0.4	0.4	0.5	0.8	1.0	1.0	1.0	1.0	1.0	1.0	10
Mm	0	75	14	19	35	79	91	63	23	76	67	116	658
3 JUNE CUT - c/f	1.0	1.0	0.4	0.4	0.4	0.5	0.8	1.0	1.0	1.0	1.0	1.0	10
Mm	65	0	75	19	26	44	66	63	23	76	67	116	639
4. JULY CUT - c/f	1.0	1.0	1.0	0.4	0.4	0.4	0.7	1.0	1.0	1.0	1.0	1.0	10
Mm	65	59	0	75	26	32	53	63	23	76	67	116	654
5. AUGUST CUT - c/f	1.0	1.0	1.0	1.0	0.4	0.4	0.6	0.9	1.0	1.0	1.0	1.0	10
Mm	65	59	46	0	75	32	40	49	23	76	67	116	648
6. SEPTEMBER CUT - c/f	1.0	1.0	1.0	1.0	1.0	0.4	0.4	0.7	1.0	1.0	1.0	1.0	11
Mm	65	59	46	57	0	75	15	21	23	76	67	116	619
7. OCTOBER CUT - c/f	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0.4	0.8	1.0	1.0	1.0	11
Mm	65	59	46	57	79	0	75	21	1	76	67	116	620
8. NOVEMBER CUT - c/f	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0.5	0.8	1.0	1.0	11
Mm	65	59	46	57	79	102	0	75	30	45	67	116	681
9. DECEMBER CUT- c/f	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.4	0.5	0.8	1.0	11
Mm	65	59	46	57	79	102	91	0	75	2	40	116	729
Total mm	531	446	344	386	469	567	524	375	183	573	576	927	5903
Mean mm	59	50	38	43	52	63	58	42	20	64	64	103	656

USL Irrigation Requirements (Ml) for Millcane from 1/04/2013 - 31/03/2014

Ha	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
APR	75	18	25	44	70	102	91	63	23	76	67	0	654
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	75	14	19	35	79	91	63	23	76	67	116	658
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUN	65	0	75	19	26	44	66	63	23	76	67	116	639
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUL	65	58.9886957	0	75	26	32	53	63	23	76	67	116	654
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	65	58.9886957	46	0	75	32	40	49	23	76	67	116	648
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
SEP	65	58.9886957	46	57.05324111	0	75	15	21	23	76	67	116	619
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCT	65	58.9886957	46	57.05324111	79.4573913	0	75	-21	1	76	67	116	620
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOV	65	58.9886957	46	57.05324111	79.4573913	101.8365217	0	75	30	45	67	116	681
114.6	75	68	53	65	91	117	0	86	35	51	77	133	780
DEC	65	58.9886957	46	57.05324111	79.4573913	101.8365217	91	0	75	2	40	116	729
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL Ml													
114.6	75	68	53	65	91	117	0	86	-35	51	77	133	780

USL Irrigation Requirements (Ml) for Non Harvest from 1/04/2013 - 31/03/2014

Ha	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
PRE-APR	75	18	25	44	70	102	91	63	23	76	67	124	778
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
APR	0	0	0	0	0	0	0	0	0	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	0	0	0	0	0	0	0	0	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUN	0	0	0	0	0	0	0	0	0	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
JUL	65	59	100	75	26	32	53	63	23	76	67	116	754
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
AUG	0												
	0	0	0	0	0	0	0	0	0	0	0	0	0
SEP	0	0	0	0	0	0	0	0	0	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	70	1	0	1	1	1	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0	0	0	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
DEC	0	0	0	0	0	0	0	0	70	0	0	0	0
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL (Ml)													
0.0	0	0	0	0	0	0	0	0	0	0	0	0	0

Centre pivot efficiency assumed at 85%

USL Irrigation Requirements (ml) for all Cane from 1/4/2013 - 31/03/2014

	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	TOTALS
DEMAND ALL CANE (Ml)	75	68	53	65	91	117	0	86	-35	51	77	133	780
REGEN (Ml)	0	0	0	0	0	0	0	0	0	0	0	0	0
SUPPY REQUIRED (Ml)	75	68	53	65	91	117	0	86	35	51	77	133	780
LOSSES (Ml)	11	10	8	10	14	18	0	13	5	8	12	20	117
(@ 0.15 %)													
TOTAL SUPPLY REQUIRED (Ml)	86	78	61	75	105	134	0	99	40	59	88	153	897
(INCLUDING LOSSES @ 0.15%)													
PUMP - IRRIG. DEPT (L/s)	33	30	23	29	40	52	0	38	16	23	34	59	
Running Pumps Required	2	2	2	2	2	2	0	2	2	2	2	2	
Kw	90	90	90	90	90	90	0	90	90	90	90	90	
Kwh	16480	14915	11631	14426	20091	25749	0	18963	7709	11294	16938	29305	172087
Cost/kWh	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	
Cost	12195	11037	8607	10675	14867	19054	0	14033	5705	8357	12534	21686	
Cost/ha	106.4	96.31	75.1	93.15	129	166.2	0.00	122.4	49.78	72.9	109	189.23	
											Total Ml/Ha (nett)		**6.81**

	PUMPS			
Kw	**Capacity of**	**Capacity of**	**No. of pump**	**Total Flow (L/s)**

	each pump (m3/hr)	**each pump (L/s)**	**s**		
45	220	61	1	61	1 pump running
45	210	58	2	119	All pumps running

Field	Approx. Hrvst date	Sub Area	Ha
UMM 02	14-Nov-13	P1	60.00
UMM 03	27-Nov-13	P2	54.60
			114.60

Table-5
Total water requirements for Ubombo Sugar in Mega Litres (ML)

USL Net MI	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Total
Total MI	13,602	12,865	12,105	12,163	14,128	15,286	15,119	14,280	11,382	14,670	13,735	16,011	165,346
USL Gross MI													
Total MI	14,484	13,576	12,672	12,860	14,760	16,099	15,787	14,940	11,570	15,716	14,718	17,608	174,790
TTN Net MI													
Total MI	2,432	2,432	2,432	2,432	2,432	2,432	2,432	2,432	2,432	2,432	2,432	2,432	2,432
TTN Gross MI													
Total MI	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,535	2,535
Total MI Required	33,052	31,407	29,744	29,989	33,854	36,351	35,872	34,187	27,918	35,352	33,419	38,585	345,102

Table-6
Total monthly power requirements for Ubombo Sugar estate in kilowatt hours (kWh)

USL Irrigation	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	Total
Total kW Irrigation	2,672,103	2,287,216	2,155,777	2,173,915	2,546,515	3,001,691	3,106,306	2,828,264	2,699,435	3,905,309	3,384,085	3,752,931	34,513,547
USL Bulk Water Supply													
Total kW	756,000	1,062,000	1,584,000	1,631,520	1,631,520	1,338,120	1,379,520	1,332,000	1,254,600	881,640	590,040	383,040	13,824,000
TTN Irrigation													
Total kW	480,068	399,625	324,886	364,889	409,651	450,056	478,873	334,807	135,677	581,836	547,855	953,393	5,461,616
TTN Bulk Water Supply													
Total kW	552,420	552,420	552,420	552,420	709,560	973,800	1,101,660	1,101,660	1,348,800	1,322,160	1,179,600	913,200	10,860,120
Total kW Required	4,460,591	4,301,261	4,617,083	4,722,745	5,297,246	5,763,668	6,066,359	5,596,731	5,438,512	6,690,945	5,701,579	6,002,564	64,659,283
Factored 75% (kW)	3,345,443	3,225,946	3,462,812	3,542,059	3,972,935	4,322,751	4,549,769	4,197,548	4,078,884	5,018,208	4,276,184	4,501,923	48,494,463

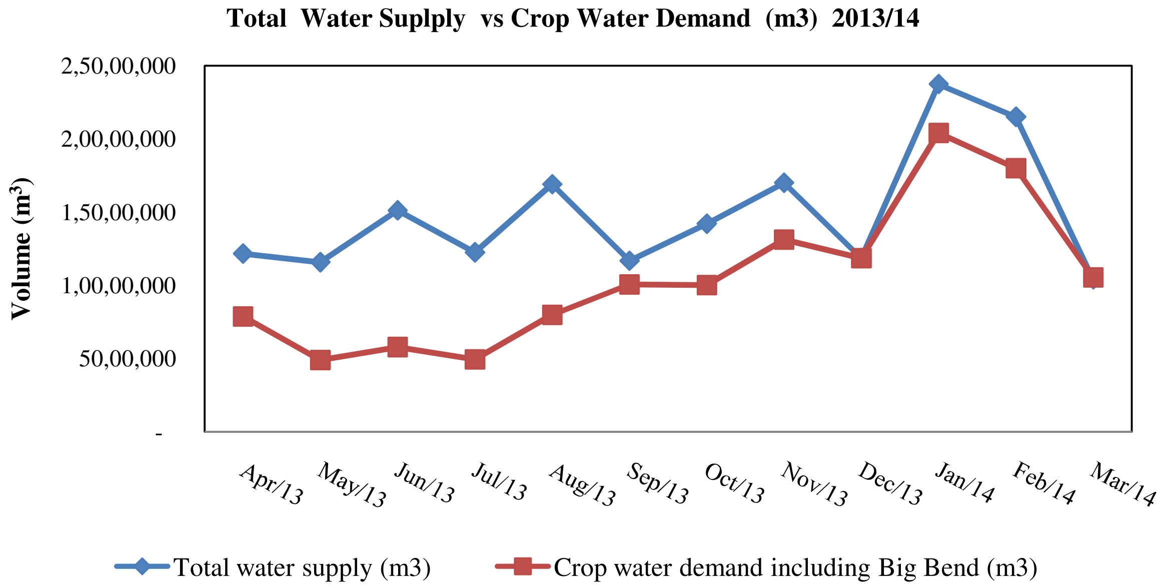

Figure-2
Actual water supply and demand curve for sugarcane at Ubombo Sugar estate

Conclusion

Existing water and power budgeting systems have demonstrated some deficiencies in capturing and consolidating all relevant parameters needed to accurately define water and electricity demand in the estate. This has led to inaccuracies on budgets which induces pressure on the resources use and subsequent stimulation of water stress and yield losses on sugarcane. Consequently, a new and improved model needs to be adopted for efficient water and power budgeting at Ubombo for effective and sustainable supply of irrigation water.

Recommendations: i. Accurately define parameters of major importance and develop a new water and power budget from first principles. ii. Install water measuring devices to quantify water used for other uses from the bulk water system. iii. Investigate agricultural power reticulation system within the estate to specifically determine actual power consumed by irrigation.

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References

1. Marlow R.L., *Water Management*; Engineering handbook, Washington DC **(2002)**

2. Hess T., Knox J., Weatherhead K., Stephens W. and Kay M., *Management of Irrigation for the Sugar Industry*. Cranfield University, United Kingdom **(2009)**

3. M. Ignatius, M. Imtiyaz and J.L.G. Kumar, Response of Cabbage (Brassica Oleracea) Under Variable Irrigation and Lateral Spacing, *Res. J. Engineering Sci*., **2**(**10**),1-9 **(2013)**

4. Shah S.M. and Mistry N.J. Evaluation of Groundwater Quality and its Sustainability for an Agriculture use in District Vadodara, Gujarat, India, *Res. J. Engineering Sci*., **2**(**11**), 1-5(**2013**)

5. Venkateswara R. S. Sastry P.G. and Ghorpsde V.G. Reservoir Sedimentation and Concerns of Stakeholders. *Res. J. Engineering Sci*., **3**(**2**), 29-32 **(2014)**

6. Aheeyar M.M.M., Innovative Strategy in Participatory Water Management: A Case of Bulk Water Allocation in Sri Lanka ; Hector Kobbekaduwa Agrarian Research and Training Institute Colombo, Sri Lanka **(2010)**

7. Baillie C.P., *Strategies for Maximising Sugarcane Yield with Limited Water in the Bundaberg District*, Department of Agricultural Engineering, University of Southern Queensland **(2009)**

8. Asian Development Bank. *Participatory Irrigation Management, Learning Lessons, Independent Evaluation Department* **(2012)**

9. Netafim, *Sugarcane Irrigation*, South Africa **(2012)**

10. Environmental Protection Agency, *Irrigation techniques and management practises* **(2009)**

11. Himanshu S.K., Kumar S. Kumar D. and Mokhtar A., Effects of Lateral Spacing and Irrigation Scheduling Cabbage (Brassica Oleracea) in a Semi Arid Region of India. *Res. J. Engineering Sci.,* **1**(**5**), 1-6 **(2012)**

12. Van Waveren E. and Nhlengetfwa J.V., *Agro-climatic characterization of Swaziland*. FAO/UNDP/GOS Land Use Planning for Rational Utilization of Land and Water Resources Project SWA/89/001. Field Doc. 1. Mbabane **(1992)**

13. Savva A.P. and Frenken K., *Irrigation Manual for Planning, Development, Monitoring and Evaluation of irrigated Agriculture with Farmer Participation.* Food and Agriculture Organization of the United Nations FAO Sub-Regional Office for East and Southern Africa, Harare **(2002)**

14. Dash S., Khatua K.K., Naik B. and Mohanty P.K., Energy Loss for a Highly Meandering Open Channel Flow, *Res. J. Enengineering Sci*., **2(4)**, 22-27 **(2013)**

15. Swaziland Sugar Association, *Management of Irrigation for the Sugar Industry* **(2009)**