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Performance of Centre Pivot Sprinkler Irrigation System and its Effect on Crop Yield at Ubombo Sugar Estate

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Abstract

The objective was to evaluate the performance of centre pivot sprinkler irrigation system and its effect on sugarcane yield at Ubombo Sugar estate to enable proposition of system configurations and management that will optimise water use and sugarcane yields. The process constituted analysis of weather parameters, design parameters, water application and uniformities, hydraulic measurements of pressure and discharge at various points in the system, system operating speed and sprinkler packages, irrigation water quality, soil physic-chemical properties, soil infiltration, soil compaction and sugarcane yields for four centre pivots (EEL09, NKA21, CAS02 and SMB). Results demonstrate that centre pivots were accurately designed and installed as they adequately supplied water to meet sugarcane demand of 7.5mm/day. Performance indicators show that centre pivots were performing relatively well as uniformity coefficients (CU and DU) for the systems were within acceptable standards above the base values of 85% for CU and 75% for DU. Application efficiencies (AELQ and PELQ) were only achieved by CAS02 and SMB as they were above the minimum of 90%. Poor infiltration as a result of compaction and clogging of sprinklers for EEL09, and lower than design pressure at pivot point for NKA21 were responsible for the sub standard application efficiencies. Soils were inherently sandy textured with a mixture of shallow and deep profiles. The physic-chemical properties indicate that soils were ideal for sugarcane growth except for shallow profiles which limited sugarcane yields due to the combined effect of low water holding capacity, reduced infiltration and hence runoff as a result of compaction by mechanical harvesting. Quality of irrigation water was within acceptable levels and had no negative impacts crop and soil. Yields were a major factor indicating the performance of the system and only EEL09 achieved low yields of 71 t/ha against 147 t/ha for CAS02, 124.8 t/ha for NKA21 and 106 t/ha for SMB. This is evidence of the performance and potential of centre pivot irrigation system. Factors affecting performance were pressure variations, clogging of sprinklers, rutting of un-gravelled tracks, shallow soils, compaction, reduced infiltration and game encroaching cane fields. Constant pressure checks, flushing of sprinklers, gravelling tracks or installing back booms, chiselling and ripping as well as fencing fields can improve system performance and sugarcane yields at Ubombo.

Keywords: Centre pivot, evaluation, irrigation, performance, sugarcane, Ubombo.

Introduction

The performance of irrigation systems is of concern in many areas of the world and has attracted the attention of researchers, planners and managers of irrigation systems in recent years[1]. Irrigation system performance plays a significant role in crop performance, water use efficiency, cost of production and income generation[2]. Although mainly used by large scale growers, centre pivot sprinkler irrigation system has also proved suitable for small scale growers in organized associations in Swaziland due to water scarcity. Recent analyses show that centre pivots are both economically and financially viable under the current pricing system in Swaziland[3]. A parallel observation has also been confirmed for sugarcane irrigation under Australian conditions[4]. The suitability of centre pivot irrigation systems in Swaziland has prompted for the rapid adoption and utilization of the system at Ubombo Sugar estate. At present, about 106 centre pivot systems are physically on the ground with a semi solid set sprinkler system in the outfall of the pivots in an attempt to improve water use efficiency, reduce labour and energy costs as well as increased in sugarcane yields and profits. The impetus on centre pivot irrigation advancement is still on owing to anticipated strategic future developments of the estate and this will eventually result into a massive increase in the percentage of the system in the estate. However, no evaluation of the performance of the system has been conducted since their introduction in the estate to establish their performance standards, influence on sugarcane yields and major factors affecting system performance. Evidence indicates that research has only been undertaken on furrow and conventional sprinkler irrigation systems where results show that there were no design parameters available for system design and poor performance is often attributed to poor management of irrigation systems. Among other factors, there is a limitation in using efficiency as the only measure of irrigation system performance because it does not show the uniformity of distribution or the percentage of the area that was adequately irrigated[5]. Ultimately, irrigation research in Swaziland has been largely focused on feasibility studies aimed at developing national irrigation schemes with less emphasis on irrigation system performance. The transition of commercial and smallholder farmers to centre pivot sprinkler irrigation necessitates extensive research on the performance of the system in order to attain greater irrigation efficiency, high water productivity and ultimate improvements on sugarcane yields.

Despite the impetus on centre pivot irrigation development, problems of the system has been observed at field level and includes uneven sugarcane growth, significant reduction in sugarcane yields, runoff and rutting of wheel tracks which often results in mechanical breakdowns and subsequent irrigation downtime. Evaluation of the centre pivot sprinkler irrigation system performance at Ubombo was therefore crucial to establish knowledge base on performance in order to justify improvements on system configurations and management, hence the purpose of this study. Evaluations included analysis of meteorological data to determine crop and irrigation water requirements, design parameters, measurements of pressure and discharge at various points in the system, pump flow rates, its operating speed, tyre pressures, water applications and inspection of sprinkler packages to determine system performance parameters and adequacy of irrigation water supply. Analysis of irrigation water quality, soil physic-chemical properties, soil infiltration, soil compaction and sugarcane yields also constituted parameters which provided basis for identification of the main factors affecting centre pivot irrigation system performance and the resultant sugarcane yields to enable proposition of pertinent system adjustments and management.

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[6]. 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. 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[7]. Both canals are kept at about 80% of maximum capacity throughout the entire growing season. 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 strategically placed 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.

Sampling of centre pivot irrigation systems: Out of 106 centre pivots that were operational, four centre pivot systems (EEL09, NKA21, CAS02 and SMB) were purposively selected for the study (figure-1). The criteria was to have a sample of centre pivots which were to be harvested at the beginning of the harvesting season, spatial representation of the net area under centre pivot irrigation, a composition of systems harvested both manually and mechanically as well as the different age categories among centre pivot machines.

Field measurements of centre pivot irrigation systems: Parameters determined included sugarcane reference evaptranspiration (ETo) using Instat software, sugarcane water and irrigation water requirements, system performance indicators, adequacy of irrigation water supply, net application rate, system operating pressure, travel speed and revolution time, spray nozzle sprinkler set and spacing, sprinkler discharge and pressure, tyre pressure, soil physic-chemical characteristics, soil infiltration, soil compaction, irrigation water quality and sugarcane yields. Design specifications for each of the centre pivots were solicited for purposes of checking the systems adequacy with regards to irrigation water supply and physical configurations on the ground. The system operating pressure, tyre pressure, travel speed, system flow rates, sprinkler nozzle discharge and pressure were measured on each centre pivot system. The effective radii of the systems were measured together with pump flow rates, pump operating pressures as well as centre pressures at pivot points. The spray nozzle sprinkler set was studied by physical observation and information from the manufacturer in the design specifications. On the other hand the colour and the number of the sprinkler nozzle which indicated its size and hence location along the lateral was also observed. This was as important as the nozzle size along the lateral for uniformity and discharge from the spray nozzle sprinkler. Spacing between spray nozzle sprinklers was measured using a measuring wheel under the sprinklers. Observations were done to identify if variation of spray nozzle sprinkler spacing along the lateral existed. The analysed results were then compared with the manufacturer's design specifications.

The physical and chemical characteristics of soils under each centre pivot were studied through laboratory analysis of samples taken for all pivots. Samples were taken using core ring samplers and soil auger at sampling intensity of one sample per 16 ha at relative depths of 30 cm intervals for 90 cm. This methodology made it possible for one sample per quadrant of each centre pivot owing to the size of the centre pivots. Samples were analysed by Mhlume Agriculture laboratory in compliance with international soil analysis standards. A double ring infiltometer was used to measure intake rate of soils for each of the pivots to study the basic infiltration rates of the soils. Compaction for the soils was measured using an automated P5 Hand Penetrometer to assess its influence on infiltration, water storage, root penetration and sugarcane yields for each of the manually and mechanically harvested centre pivot systems. Soil compaction maps showing the trends of compaction for the centre pivots were developed using ArsGIS software through geospatial interpolation of measurement points captured using a handheld Juno SB GPS. The quality of irrigation water was measured by taking water samples from the fertigation fittings located at the pivot point of each centre pivot and the source of irrigation water for each pivot either canal or night storage dam. Water samples were analysed by Swaziland Water Services Corporation (SWSC) laboratory. Sugarcane yields were obtained from the weighbridge and Canepro information system to assess the influence of the centre pivot irrigation system, soils and water on yields. Mill cane tonnes per hectare and sucrose percentage were used as indices for assessing the influence of irrigation system, soils and water on sugarcane yields.

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 software gives a maximum ETo of approximately 6 mm/day at peak demand (figure-2). Annual crop water requirement (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 satisfactory in applying the target amount as they ranged between 6.5 and 7.1 ML/ha. Design net system capacity used by Ubombo Sugar is 7.5 mm/day and the gross application rate depends on irrigation system efficiency. Centre pivots normally apply a gross amount of 8.8 mm/day and during each irrigation event, the normal irrigation practice is to apply 25mm/day[8]. For purposes of evaluation, a minimum of 16 mm/day was used and it was compliant with the base value of 15 mm/day[9]. Tables 4-5 presents system capacities, irrigation depth (D), centre pivot speed, revolution time (T) at each evaluation for all four centre pivots. Figure-3 shows the water distribution profile for all four centre pivots against a target amount. EEL09, CAS02 and SMB performed better in terms of satisfying a target depth of water although the distribution was very poor for CAS02 due to sprinkler blockage. NKA21 did not meet the target depth but it was excellent in terms of water distribution. This was attributed to lower than design operating pressure on the pump which affected the centre pressure required at the pivot point as adequate pressure is normally achieved when both pumps delivering (other supplying NKA20) in the same pipeline are in operation for this pivot. The system flow rate was measured and found satisfactory in relation to the wetted area as 48.9 l/s was obtained in the delivery pipeline of the pump dedicated for NKA21 (table-6 and figure-6). Using a hydro model of 1.0 l/s/ha derived from the gross application of 8.8 mm/day, the flow was adequate to irrigate a net area of 45.6 ha for NKA21 and this was evident for all systems (table 6). The evaluation results reveal that centre pivots were performing relatively well as parameters of CU and DU for three systems were within acceptable standards. CUs for EEL09, NKA21 and SMB were 89.7%, 94.6% and 88.7% respectively and concur with the standard of 85.0% (table-7)[10]. CAS02 did not meet the acceptable standards with a CU of 80.5%. The DU for all systems was within recommended standards with EE09, NKA21, CAS02 and SMB having 89.2%, 95.7%, 77.2% and 89.6% respectively. Centre pivot irrigation system DU should be at least 75%[11]. However, on the other hand the recommended PELQ and AELQ were only met by CAS02 and SMB with 93.3%, 98.2% and 94.4%, 90.8% respectively (table-7). EEL09 and NKA21 did not meet the recommended performance standards which states that spray nozzle sprinkler centre pivot PELQ and AELQ should be at least 90%[12]. The results implies that the systems were adequate in meeting sugarcane water requirements and the uniformity coefficients and efficiencies were generally acceptable except for the lower than expected application efficiencies of EEL09 and NKA21 which was attributed to clogging of sprinklers, compaction and poor infiltration for EEL09 and slightly lower than design operating pressure at the pivot point for NKA21.

Sprinklers for NKA21, CAS02 and SMB were applying water slightly above the design application rates. A desk review of the design specifications for sprinkler packages indicated matching configurations from the inspections in the field except for cases where sprinklers were removed near the pivot points or at the towers to avoid wetting wheel tracks or irrigation of bare land at the pivot point (figure-5). The relatively high application rates were a result of nozzle wear and replacements are essential. The design application rates for the systems were exceeded by actual application rates particularly towards the end of the lateral (figure-4). In contrast, EEL09 had no specifications for sprinklers on the design specifications hence no benchmark for assessing performance of the sprinklers (figure 3). Furthermore, there was no soil infiltration data on the design reports where the sprinkler packages could have been determined for the pivots. Predisposing factors for higher application rates included among others, the sprinkler operating pressure which for some sprinklers were found operating beyond the threshold of 100 to 140 kPa. Parallel observation was also made on the tyres where the recommended operating pressure of 100 kPa was not achieved for some systems as they recorded pressures of up to 200 kPa. Generally, this does not only affect the rims and gearboxes but also the distribution uniformity of water application along the centre pivot lateral.

Soil properties are among factors responsible for sugarcane yield in the fields. Fields EEL09, NKA21. CAS02 and SMB were sandy textured soils of up to 53% sand in the profile (Table-8). The amount of silt was slightly higher than clay content in all soils. The sandy texture could not affect sugarcane growth as it enhanced soil infiltration and drainage[14]. The inherent nature of the soils implies frequent and light irrigation to avoid percolation losses and subsequent induction of water stress to the crop. Only CAS02 had deep soils with high water storage capacity as evidenced by higher proportion of silt and clay (table-8). Chemical properties of the soils indicate that there is no salinity and sodium hazard as EC values were less than 0.7 dS/m and SAR less than 2[15]. Soil pH was slightly acid although it proved neutral for the irrigation water with slightly higher SAR values (Tables -9 and 10). Compaction measurements demonstrated that EEL09 was more compact than the other pivots as the major driver was mechanical harvesting (table-11). The compaction trend among the fields had an effect on infiltration rates of soils in the pivots. EEL09, a sandy textured soil was found to be behaving more like a clay soil with a basic infiltration rate of 6 mm/h in one of the quadrants while the other less compact fields had infiltration rates greater than 70 mm/h (table-12). This is typical evidence of the effect of compaction on water entry into the soil and hence runoff and subsequent induction of water stress to sugarcane. Table-13 presents yields for each of the centre pivots as influenced by the performance of the centre pivot system, soil and water characteristics as well management aspects. EEL09 recorded low yields of 71 t/ha as opposed to 147 t/ha and 124.8 t/ha for CAS02 and NKA21. The low yields were attributed to shallow soils with low water holding capacities (table-8), compaction due to mechanical harvesting, reduced soil infiltration and encroachment of sugarcane by wild animals. The slightly higher application rates of worn out sprinklers implies that water is generally not infiltrating the soil but rather generating runoff which ultimately reduces the application efficiency of the system. Wear and eventually crashing of the mechanical centre pivot structure is often attributed to wheels driving on deep un-gravelled tracks and this induces irrigation downtime.

Figure-1
Layout of Ubombo Sugar estate and centre pivots studied

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

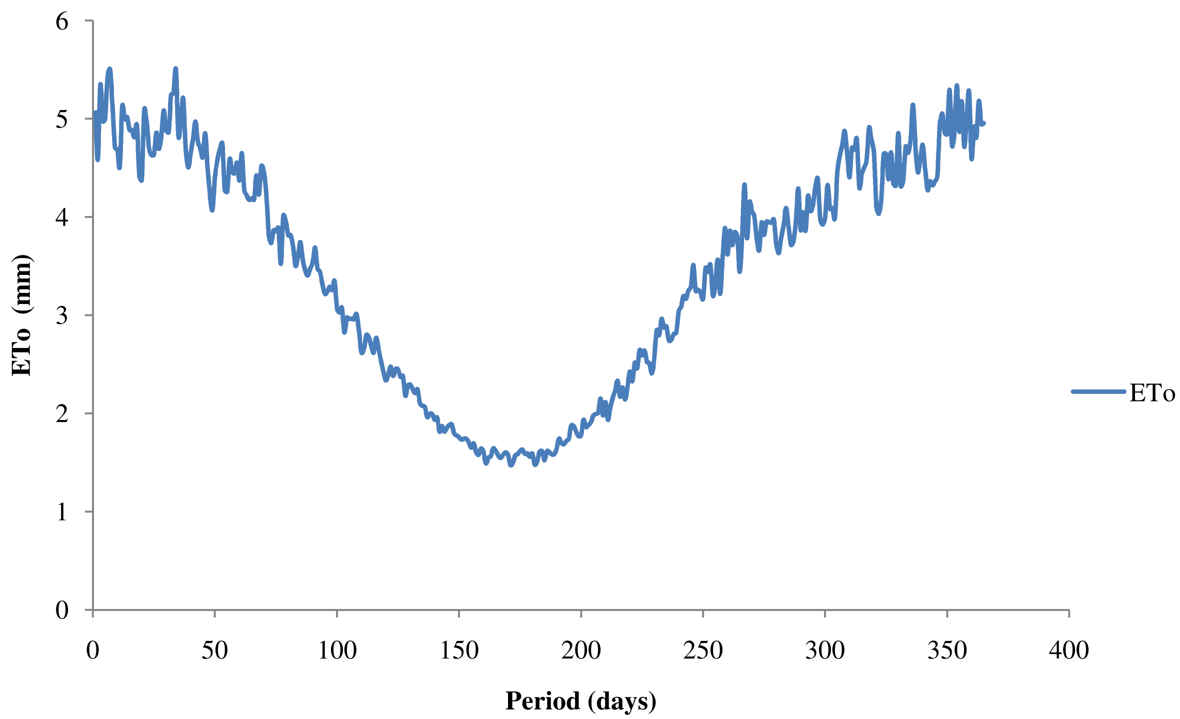


Figure-2
Reference evapotranspiration (ETo) for Big Bend

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

Source: Swaziland Sugar Association (1995)[13]

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

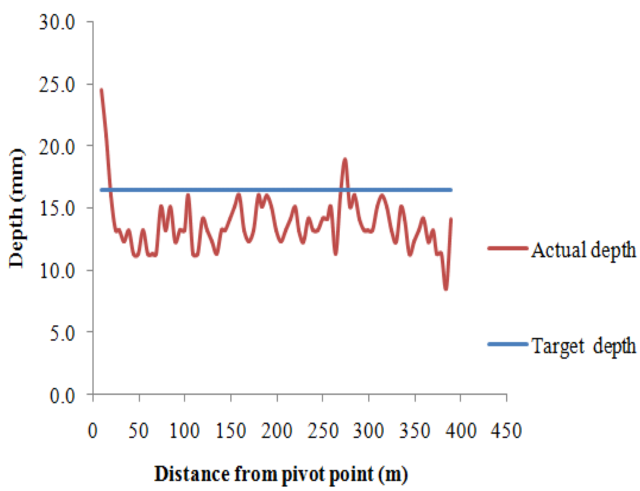
ETo = reference evapotranspiration (mm/month), c/f = canopy factor, ETc = cane evapotranspiration (mm/month), R = rainfall (mm), Re = effective rainfall (mm), IRR = irrigation requirement (mm)

Table-4
Performance parameters for centre pivots EEL09, NKA21, CAS02 and SMB

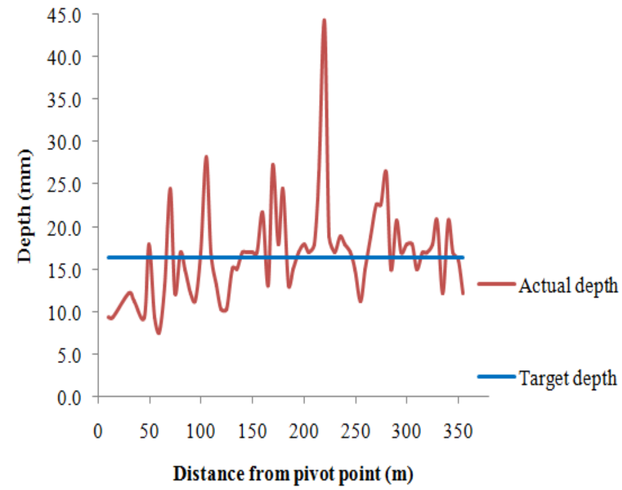
Centre pivot	Wetted area (ha)	Time per rev. (hrs)	CP speed (mm/min)	Pressure (Bar)
EEL09	49.1	42.8	935.0	3.1
NKA21	45.6	42.3	973.3	3.3
CAS02	36.5	34.9	973.3	1.4
SMB	70.4	46.3	1013.3	3.0

Table-5
System capacities and net crop water demand for centre pivots EEL09, NKA21, CAS02 and SMB

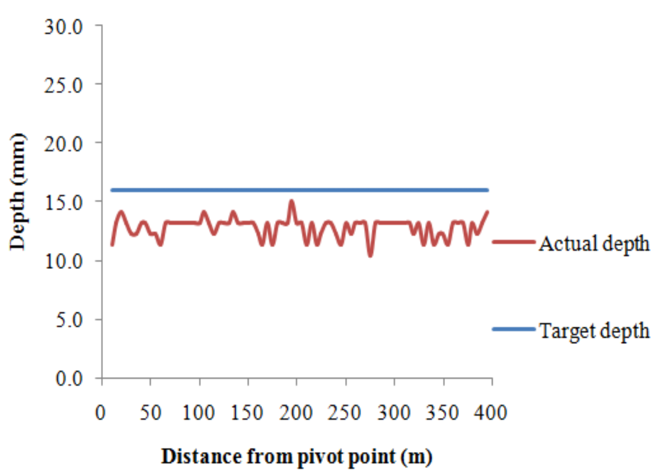
Centre pivot	Design flow rate (m^3/h)	Actual flow rate (m^3/h)	Flow rate (l/s)	Flow rate (ML/day)	Crop demand (mm/day)
EEL09	191.9	178.6	49.6	4.3	7.5
NKA21	200.0	176.0	48.9	4.2	7.5
CAS02	130.0	133.6	37.1	3.2	7.5
SMB	253.1	257.0	71.4	6.2	7.5



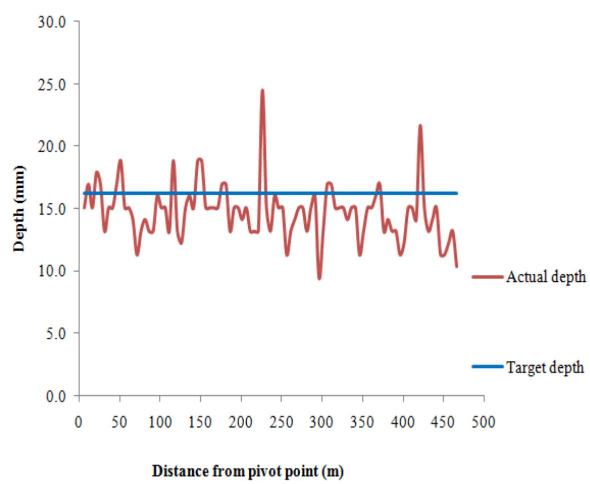
(a) EEL09 water application



(c) CAS02 water application



(b) NKA21 water application



(d) SMB water application

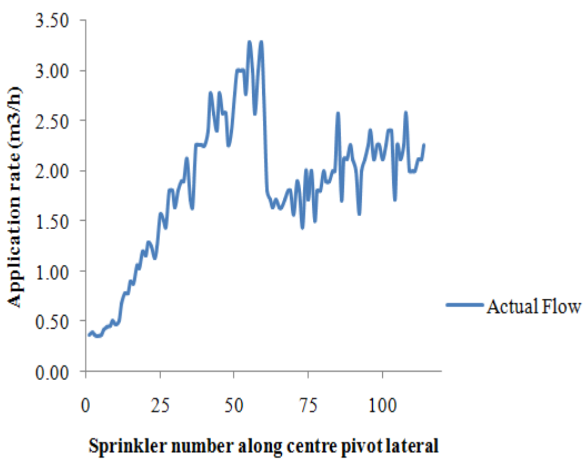
Figure-3
Water distribution profile along the lateral radii of EEL09, NKA21, CAS02 and SMB centre pivots

Table-6
Crop water requirement and adequacy of water supply for centre pivots EEL09, NKA21, CAS02 and SMB

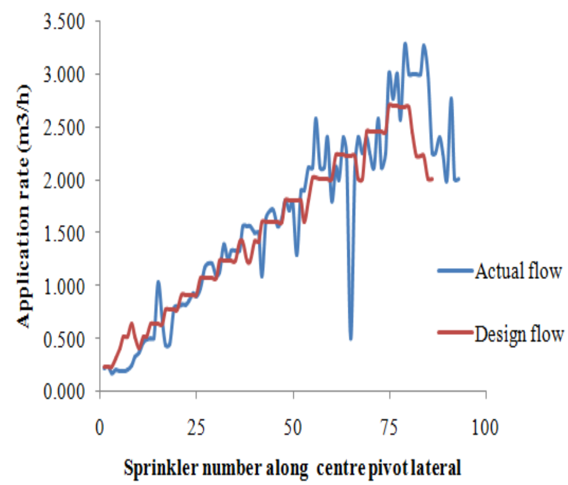
Parameter		EEL09	NKA21	CAS02	SMB
		(49.1 ha)	(46.5 ha)	(36.5 ha)	(70.4) ha
ETo (mm/day)	6.0	6.0	6.0	6.0	6.0
Kc (sugarcane)	1.25	1.25	1.25	1.25	1.25
Net application (mm/day)	7.5	7.5	7.5	7.5	7.5
Gross application (mm/day)	8.8	8.8	8.8	8.8	8.8
Equivalent flow rate (l/s/ha)	1.0	49.6	48.9	37.1	71.4

Table-7
Performance indicators for centre pivots EEL09, NKA21, CAS02 and SMB

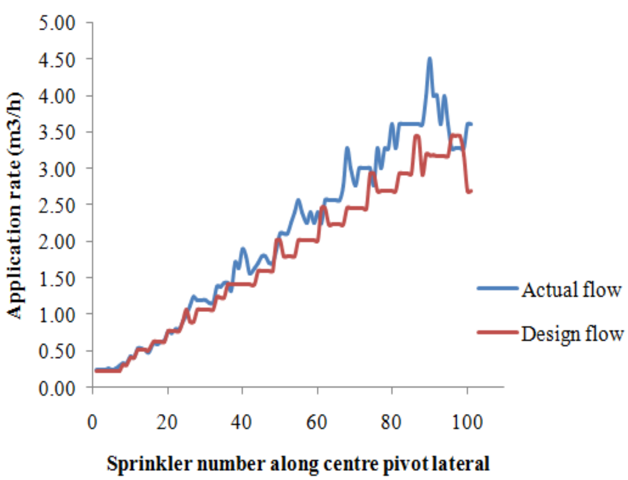
Centre pivot	CU (%)	DU (%)	PELQ (%)	AELQ (%)	Depth (mm/day)	Time (hrs)
EEL09	89.7	89.2	84.8	83.5	13.7	42.8
NKA21	94.6	95.7	81.3	80.0	12.8	42.3
CAS02	80.5	77.2	93.3	98.2	16.2	34.9
SMB	88.7	89.6	94.4	90.8	14.7	46.3



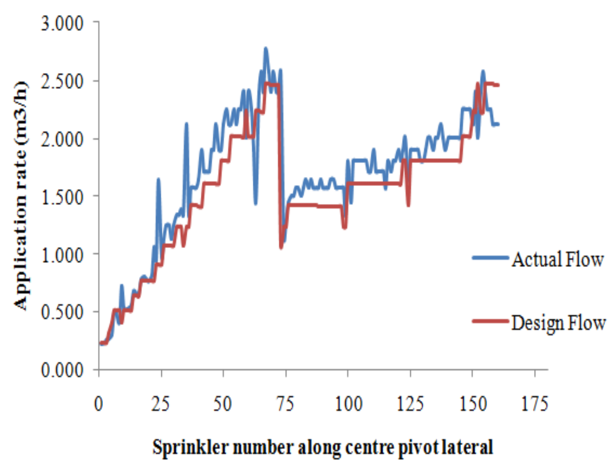
(a) EEL09 sprinkler application rate



(c) CAS02 sprinkler application rate



(b) NKA21 sprinkler application rate



(d) SMB sprinkler application rate

Figure-4
Sprinkler application rate along the lateral of EEL09, NKA21, CAS02 and SMB centre pivots

Figure-5
Sprinkler package inspection and operating pressure measurement in one of the centre pivots while in operation

Figure-6
Pump flow rate measurement in the delivery pipeline of the pumps supplying NKA21 using a portable flow meter

Table-8
Soil physical properties for EEL09, NKA21, CAS02 and SMB centre pivots

Field	Organic Matter (%)	Bulk Density (g/cm^3)	Porosity (%)	Particle size Distribution (%)			
				Clay	Silt	Sand	Text. Class
EEL09	1.82	1.32	50.24	14.47	32.9	52.63	Sandy
NKA21	1.76	1.27	51.92	17.33	34.13	48.55	Sandy
CAS02	1.28	1.34	49.32	9.98	45.68	44.35	Silty sand
SMB	1.60	1.33	49.77	14.55	36.45	49.0	Sandy
		@100 kPa	@1500 kPa	RAM (mm/m)	% Moisture	Saturation (g)	
EEL09	274.67	271.99	269.64	35.2	30.99	287.66	
NKA21	265.1	261.57	257.96	44.44	23.09	277.7	
CAS02	261.26	256.8	253.43	60.0	33.74	267.53	
SMB	275.58	272.81	266.92	36.54	25.55	288.04	

Table-9
Soil chemical properties for EEL09, NKA21, CAS02 and SMB centre pivots

Field	pH	EC (mS/m)	SAR	T.S.C (Meq/L)	Na (Meq/L)
EEL09	6.33	0.3	1.09	3.48	1.17
NKA21	6.51	0.3	1.23	2.75	1.11
CAS02	7.21	0.4	2.18	4.50	2.29
SMB	6.75	0.3	1.42	2.94	1.24

Table-10
Irrigation water quality parameters for sources supplying EEL09, NKA21, CAS02 and SMB centre pivots

Field	pH		EC (mS/m)		SAR		TDS (mg/L)		TSS (mg/L)	
	CP	Dam/Canal	CP	Dam/Canal	CP	Dam/Canal	CP	Dam/Canal	CP	Dam/Canal
EEL09	7.5	7.7	0.3	0.2	5.4	6.3	93.3	75.4	26	30
NKA21	7.7	7.6	0.2	0.2	5.8	5.8	116.1	115.8	12	14
CAS02	7.6	7.7	0.3	0.2	7.9	5.1	142.5	107.2	0	40
SMB	7.8	7.9	0.1	0.1	4.8	5.4	51.4	51.0	140	146

Table-11
Average soil compaction values for EEL09, NKA21, CAS02 and SMB centre pivots

Test centre pivot	Area (ha)	Soil depth (cm)	A	B	C	D
			2500*	2500*	2500*	2500*
EEL09	49.1	0-15	1211	2471	1981	3678
		0-30	1523	3822	2538	3601
		0-60	2970	4100	4330	5223
NKA21	45.6	0-15	627	565	-	-
		0-30	877	1230	-	-
		0-60	1467	1832	-	-
CAS02	36.5	0-15	534	467	355	433
		0-30	805	704	658	662
		0-60	1064	942	1157	1280
		0-90	1215	1098	1430	1657
SMB	70	0-15	849	720	298	621
		0-30	1251	1007	869	1006
		0-60	2279	2644	1313	1852

A, B, C, D – centre pivot quadrants as function of pivot size, *Maximum penetration resistance ideal for sugarcane root growth

Table-12
Soil basic infiltration rates for EEL09, NKA21, CAS02 and SMB centre pivots

Centre pivot quadrants	EEL09	NKA21	CAS02	SMB
A	-	102	78	-
B	-	72	-	138
C	6	-	180	-
D	120	-	-	216

Table-13
Yields for EEL09, NKA21, CAS02 and SMB centre pivots

Yields	EEL09	NKA21	CAS02	SMB
TCH (t/ha)	71	124.8	147	106.2
Sucrose (%)	12.3	11.3	12.7	13.6

Conclusion

Centre pivots are performing relatively well and continue to be the system of choice at Ubombo Sugar estate. The appreciable performance conditions are attributed to accurate design and installation of the system, scheduled maintenance and management among other factors. Pressure variations, clogging of sprinklers, rutting of un-gravelled tracks are factors affecting the performance of the system and needs to be reviewed although performance indicators were found within acceptable standards. Major factors limiting centre pivot irrigation potential on sugarcane yields includes shallow soils with low water holding capacities, compaction, reduced infiltration and game encroaching sugarcane fields.

Recommendations: i. Constantly check system, sprinkler and tyre pressure and correct any deviations. ii. Flush centre pivot lateral and sprinklers to avoid sprinkler clogging. iii. Gravel wheel tracks or install back boom sprinklers along towers to prevent wheel ruts. iv. Chiselling every cut and ripping during plough-out for mechanically harvested fields. v. Upscale research on effects of mechanical harvesting to develop management procedures. vi. Fence off fields at the vicinity of nature reserves to eliminate cane damage by wild animals.

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