DEVELOPMENT OF THE CENTRE PIVOT IRRIGATION SYSTEM IN MAURITIUS

M Teeluck

Mauritius Sugar Industry Research Institute

ABSTRACT

The centre pivot irrigation system has only been recently introduced in Mauritius and yet it occupies almost 25% of the irrigated sugar cane area belonging to miller-planters. Its relative ease of operation, low energy and labour requirements as well as its lower investment cost compared to drip systems are among the arguments which explain the rapid expansion of the system. This paper presents an overview of centre pivot irrigation in Mauritius and examines some of the reasons for its adoption. The centre pivot irrigation scheduling software IRRIPIVO designed by MSIRI is briefly explained. The performance of the system and the quality of water application obtained under different operating conditions are discussed in terms of achievable cane yields and irrigation uniformity. Stress is laid on the importance of the system maintenance as this aspect is considered to be crucial for the sustainable use of the system. Some limitations which may prevent a wider use of the system in Mauritius are also analysed.

INTRODUCTION

It is generally accepted that irrigation is one of the cultural practices that stabilises yields and improves productivity in any agricultural development. In Mauritius, in order to sustain cane production, irrigation is practised intensively in most of the Western sector and partly in the Northern sector - two sectors which contribute to about 30% of the total sugar production. In other areas such as the sub-humid and humid climatic zones where rainfall is relatively higher, supplementary irrigation is also necessary to make up for the erratic distribution of rainfall and to stabilise cane yields. Furthermore, given the shallow nature of the soils with a low water holding capacity, irrigation is necessary during certain periods of the year even where annual rainfall may reach 2000 mm.

Irrigation in Mauritius has long been associated with surface and overhead or sprinkler systems. Since the 1950s several high pressure and high volume sprinklers such as the Boom-o-Rain, Target Masters and Rain Guns have been introduced and are well adapted with the existing cropping system. However, with the rising cost of energy and an increasing competition for the available water, these high pressure systems are gradually being phased out and replaced by medium to low pressure systems such as the dragline and fairly recently by the mechanised and automated centre pivot system.

The centre pivot system is considered as a significant development in Mauritius and since its introduction in 1990, the number of operating units has been increasing among both miller-planters and large-planters, to reach at present a total of about 60 units irrigating an area of about 3000 hectares. This paper presents an overview of the centre pivot irrigation system and examines some of the reasons for its rapid adoption by sugar cane planters. The irrigation scheduling software, *IRRIPIVO* developed by MSIRI is briefly explained and the performance of the centre pivot is then examined in terms of water application uniformity and achievable yields. The last part emphasises the importance of maintenance aspects and analyses some limitations to a wider use of the system.

SYSTEM DESCRIPTION

The centre pivot system is classified as a medium to low pressure sprinkler system capable of irrigating large circular areas. It consists of a single galvanised steel lateral which rotates about a fixed point in the centre of the irrigated field. The lateral, equipped with nozzles or sprinklers, consists of 40 to 50 m long spans, each supported above the crop with as much as 3 m clearance by A-shaped steel frames (towers) mounted on powered wheels. Steel cables or trusses between the towers provide the strengthening support to the system. Starting from the pivot point, each additional span irrigates a larger area than the previous one. Therefore, for economic design centre pivots are reasonably long. Centre pivot systems 400 m long (irrigated area of about 50 hectares) are quite common in Mauritius, and a few systems even reach up to 850 m.

Centre pivot systems are electrically driven. Each tower has an electric motor that drives the wheels through a gear box. The rotary movement of a pivot can be adjusted to meet the crop water requirement. The slower the lateral moves, the more water is applied. The movement of the system and therefore the depth of irrigation applied is controlled by regulating the speed of the outer most tower from a control panel located at the centre point. The advance of the last tower sets the other towers into motion one after the other by a system of sensors located on each tower and which is activated when the angle between the spans exceeds a pre-set limit. The sensor at each tower switches off again once a pre-set angle in front is reached. Each span therefore advances in short bursts starting with the next to last tower and progressing inward towards the pivot point. Safety devices present on the system stop the machine automatically whenever there is any malfunctioning. To ensure a uniform depth of water applied, the centre pivot system is equipped with either nozzles of different sizes spaced regularly along the lateral or with similar sized nozzles spaced more closely towards the lateral end.

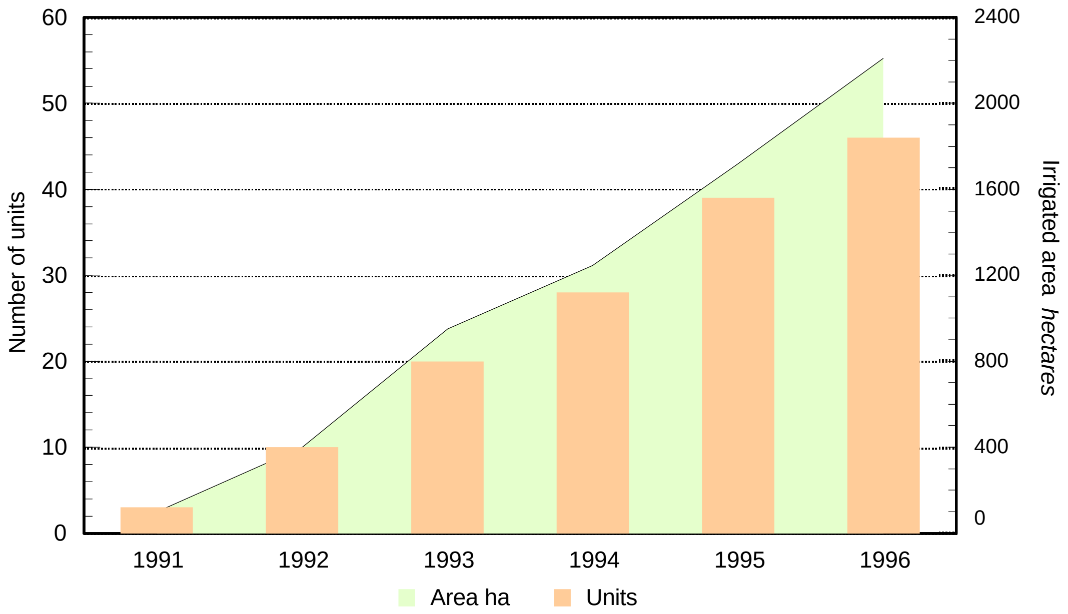
RAPID ADOPTION OF THE CENTRE PIVOT SYSTEM

The centre pivot system was introduced in Mauritius at a time when the sugar industry was facing an acute labour shortage and an increase in energy cost. Several cultural practices had to be mechanised and the centre pivot system provided an ideal tool for a form of automated irrigation. Indeed, since its introduction in 1990, there has been a spectacular increase in the area under centre pivot irrigation as shown in **Figure 1**. Ah Koon (1994) attributes this rapid adoption to three main reasons: first, there was a pressing need to replace the existing high pressure overhead system which was becoming too costly to operate, in favour of systems like the centre pivot which require about half of the pressure (200 to 300 kPa) and hence less pumping costs than the existing system. Secondly, the system being mechanised, it is possible to irrigate large areas with reduced labour intervention and thirdly, the investment cost of the system is by far inferior to the drip system which has been claimed to be one of the potential replacements for the overhead systems. Indeed, the cost of a centre pivot ranges, on average, from 25 000 to 35 000 MUR ha^{-1} [*] compared to MUR 60 000 to MUR 80 000 for the drip system. Also the operating cost of a centre pivot system can be as much as four times lower than that of a comparable conventional sprinkler system. For example at Médine Sugar Estate, operation cost (labour and energy costs) amounts to about 4.50 to 6.00 MUR $mm^{-1}ha^{-1}$ for the centre pivot compared to 15 to 20 MUR for the Boom-o-Rain.

The centre pivot has also other features that make it attractive to irrigation managers. It is easy to operate and does not require trained personnel. Water application can be easily adjusted to meet the soil and crop requirements. It also has greater management flexibility than other sprinkler systems. The system can be managed so as to apply the crop requirement either in small frequent doses or in one single application. Some models are computerised and therefore offer additional versatility.

[*] 1 MUR = 0.04545 USD approximately

Figure 1 Evolution of the centre pivot irrigation system in Mauritius



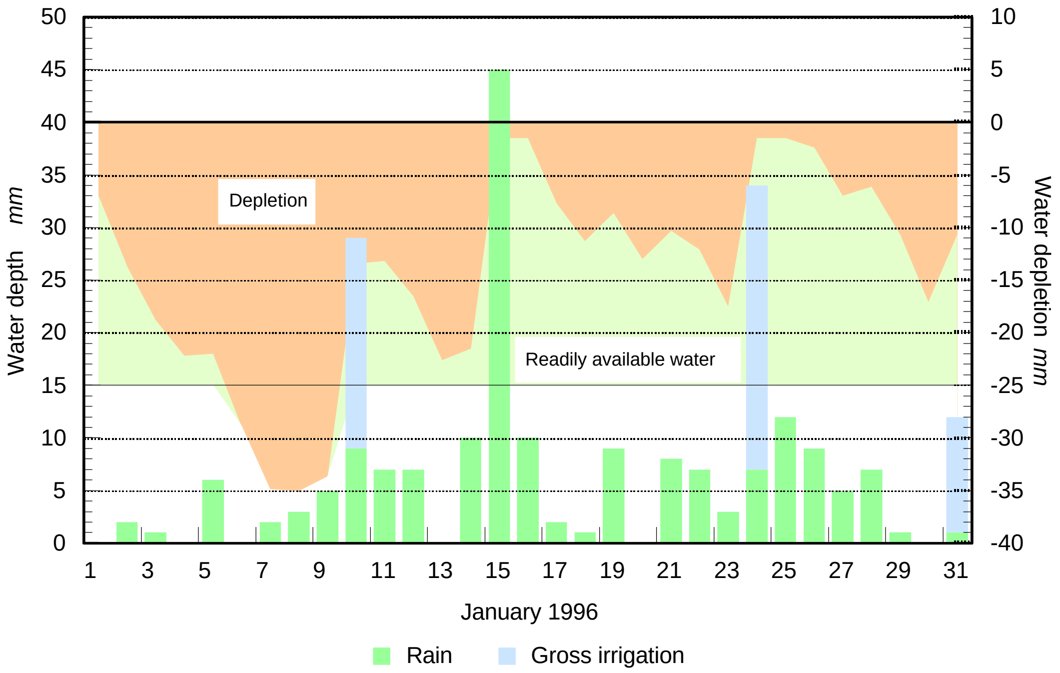
THE SOFTWARE, *IRRIPIVO*

The software *IRRIPIVO* has been developed by MSIRI to assist centre pivot users to monitor their irrigation. It is based on the principle of budgeting the soil moisture of the root zone and it forecasts the next irrigation when a pre-set root zone depletion has been reached. Before *IRRIPIVO* can be run, data files need to be created in which the characteristics of the centre pivot, soil and crop parameters as well as irrigation management options are input. The software incorporates a data bank of water holding capacity of the different soil types, so that it may be used without prior soil testing. Once the data files are created, the user has just to input daily weather data (rainfall and adjusted pan evaporation or Penman evapotranspiration) and any previous irrigation applied. By keeping track of the moisture depletion in the root zone, the next irrigation amount is displayed when the readily available soil moisture (RAW) in the root zone reaches a pre-set level. The irrigation duration as well as the required speed of movement of the centre pivot are also displayed. Various levels of output can be chosen from daily to weekly output or annual summary sheets as well as a graphical display (**Figure 2**). The output shows the evolution of soil moisture reserves, the water balance component, the frequencies and the amounts of irrigation and rainfall. The graphical display appears to be better assimilated by the users and has proved to be more useful for decision making than the summary sheets. The amount of water applied with *IRRIPIVO* compares well with the amount used under the estate scheduling practices. For example, at Mon Désert Mon Trésor Sugar Estate, about 750 mm of water were applied for a period of ten months under *IRRIPIVO* compared to about 800 mm for an adjacent centre pivot without the software. Presently the software is under DOS environment, possibilities for a WINDOWS version are now envisaged.

SYSTEM PERFORMANCE

The performance of the centre pivot system has been evaluated by measuring the uniformity of water application under various operating conditions. The measure of irrigation uniformity most commonly used for the centre pivot system is the Christiansen's Coefficient of Uniformity (CU) expressed as a percent and based on the absolute deviation from the mean application depth. The method used to measure this uniformity coefficient is that of Hermann and Hein (1968) which was adopted by the American Society of Agricultural Engineers (ASAE 1991). Uniformly spaced cans are placed along the radius of the Centre Pivot lateral and CU is calculated from the amount of water collected in each can weighted for the difference in area represented by each can. The weighting accounts for the increase in area represented by successive cans as they progress toward the lateral end.

Figure 2 Sample output from *Irripivo V 2.5* software



Results of twelve tests covering seven centre pivot units in different localities show that CU ranges from 68 to 85% and varies according to conditions imposed by climate, operating pressure, speed and direction of movement of the machine and also the type of nozzles used (Anon 1992, 1993, 1995, 1996). The effect of the type of nozzles on the performance of the centre pivot is shown in **Table 1**. Low drift nozzles with a mean CU of 85% seem to perform better than the standard spray nozzles (CU: 78%) under the conditions of the tests.

Table 1 Coefficient of uniformity (CU) of two centre pivots at Deep River Beau Champ Sugar Estate

Test No	Wind Speed *km h⁻¹*	Relative humidity *%*	Standard spray nozzles *CU %*	"Senninger" low drift nozzles *CU %*
1	20.8	70.0	77	84
2	21.4	69.0	79	85
3	13.9	84.0	80	86
Mean	14.0	74.0	78	85

A comparison of the centre pivot CU results with the dragline system with reported CU values ranging from 57 to 67% (Anon 1996) and Rain Guns with CU ranging from 60 to 75% (Nicolin 1986), reveals the superiority of the centre pivot system to the other overhead systems with respect to water application uniformity. Does this improved application uniformity translate into improved cane yields? This is difficult to answer because available data on the different irrigation systems do not always allow a proper comparison. There are however some indications as shown in **Table 2** that the centre pivot system produces better cane yields. Indeed, irrespective of locality or crop category, a centre pivot system produces on average about 20 t ha^{-1} more than the dragline system. However, the centre pivot system uses about 200 mm more water than the dragline.

Table 2 Cane yields of variety R570 under different irrigation systems

Estate	Section	Year	Crop category	Centre Pivot*	Dragline*
				t ha $^{-1}$	
Belle Vue	Solitude	1993	2nd R	101	86
Belle Vue	Solitude	1994	3rd R	113	83
Belle Vue	Ferret	1996	3rd R	103	80
Médine	R.Brunes	1994 - 1996	Mean**	128	109

Note: * Water applied: C. pivot = 850 - 1000 mm, dragline = 700 - 900 mm
** Mean = average of plant cane,1st and 2nd ratoon crops

The superiority of the centre pivot system is also apparent in the commercial yield obtained in some sugar estates. An overall commercial yield increase of about 15 t ha^{-1} has been reported at Médine Sugar Estate by switching from a surface irrigation system to the centre pivot system. Although commercial yields as reported by the sugar estates do not always provide a reliable measure of comparison, in that yields of different cane categories or different methods of harvest are pooled together, the data presented in **Table 3** nevertheless illustrate that irrespective of variety, cane yields obtained under the centre pivot are higher than those obtained from the other overhead systems.

Table 3 Achievable commercial cane yields (*t ha*$^{-1}$) with different irrigation systems at Belle Vue (Ferret Section**)**

Varieties	Centre Pivot		Dragline		Target Master	
	1995	1996	1995	1996	1995	1996
M1557/70	86.4	93.0	-	-	74.8	79.1
M1658/78	85.6	118.7	77.6	89.5	81.5	101.0
R 570	81.0	93.0	77.1	88.7	74.4	79.5

SYSTEM MAINTENANCE

In order for centre pivot users to obtain high irrigation efficiencies with the system, it has to be well designed, properly installed and above all well maintained. Compared to other irrigation equipment, the centre pivot has a lot of moving parts which are liable to wear and tear. As the system is electrically powered, a regular supervision of the sensors, safety devices and other electrical components is required to make full use of their possibilities and life span. Indeed, Hillel (1987) pointed out that in a sprinkling system, the danger of system failure increases with technological complexity, requirement of expertise and quick availability of spare parts.
Teeluck and Ah Koon (1996) reported that centre pivots in Mauritius operate in difficult weather and terrain and most centre pivots are found in areas not far from the sea and are therefore exposed to sea spray. Moreover, sloping terrain conditions and sometimes development of deep ruts in the wheel tracks affect the life span of gearboxes and motors. The long hours of operation (2000 to 5000 hours annually) and the nature of the crop (sugar cane) which causes friction of the vegetation with the moving parts, may cause additional stress and deterioration of the equipment. Regular servicing of gearboxes, motors and other accessories are recommended on a twice monthly basis during the irrigation period. An entire revision of the electrical components, nozzles, as well as the gearbox and motor are also necessary on an annual basis.

Emphasis should also be laid on the proper anchorage of the centre pivot during cyclonic periods. Steel cables (6 - 10 mm diameter) or nylon ropes (20 - 25 mm diameter) are recommended. The minimum requirement for the anchorage is to have at least one attachment point on each span linked to two anchor blocks in an inverted V shape and one attachment point on each wheel linked to another two anchor blocks. Further details are given in the centre pivot operation and maintenance manual produced by MSIRI (Teeluck and Ah Koon 1996).

PROBLEMS AND PROSPECTS

Centre pivot users are enthusiastic about the system on account of its performance and the number of units has been increasing every year. The system has, however, some limitations which may prevent its wider use in Mauritius. The nature of the terrain may impose some restrictions on the use of the centre pivot. The system is not particularly suitable for hummocky and sloppy terrain conditions. Slopes above 10 to 15% gradient are not recommended to avoid excessive stress on the machine. The irrigated area has to be free from obstacles like trees, streams, power lines, rock piles, etc. Lengths are often limited by high instantaneous application rates (IAR) inevitable at the outer end of centre pivots. Results of recent tests carried out on a 860 m-long centre pivot at Deep River Beau Champ Sugar Estates suggest IAR values of the last span ranging from 78 to 135 mm h^{-1}. Such long systems are only suitable for soils with high permeability (e.g. Latosolic Reddish Prairie - P soils). The centre pivot system is not recommended in heavy clay soils such as the Dark Magnesium Clay found at Magenta or the Grey Hydromorphic soil of Balaclava. These soils have a low permeability which can be less than 10 mm ha^{-1} and are also sticky when wet and may cause the tower wheels to slip.

Another major limitation of the centre pivot is the circular irrigation pattern. In a square field, this leaves 21% of land unirrigated. This circular configuration is a severe limitation of the Centre Pivot system in the Australian sugar industry (BSES 1991). As a solution to this problem, some manufacturers offer corner systems which swing out to irrigate the corner, but the benefits derived from such systems may be offset by additional costs and the complications added to an otherwise remarkably simple system. In Mauritius, centre pivot owners are using sprinkler systems like dragline to irrigate the corners. Another problem linked with the circular configuration of the centre pivot is its inability to apply different amounts of water within the irrigated area other than in sectors of a circle. Different irrigation amounts cannot be applied to other shapes within the circle. This can be a problem when fitting a centre pivot into an existing layout with crops requiring different irrigation amounts.

The susceptibility of the centre pivot to damage by cyclonic winds may be another limitation of the system in Mauritius. During cyclone ‘Hollanda’ in 1994, a few units in the North and West suffered considerable damage. Proper cyclone precaution schedules such as those proposed by Teeluck and Ah Koon (1996) are therefore necessary to limit cyclonic damage

CONCLUSION

The centre pivot system appears to satisfy the immediate needs of irrigators in that it provides a uniform irrigation to large areas with moderate pressure and with very little labour. Cane growers are particularly enthusiastic about the system and it can be expected that more units will be installed in the near future. There is however a need for a proper comparison of the water use efficiency and the economics of the system with the other irrigation systems before the centre pivot can be fully assessed.

In conclusion it is worth quoting Hillel (1987) to emphasise on the need for proper maintenance of the system.

> “Centre pivot systems are beautifully efficient as long as they operate perfectly, but without expert maintenance, and spare parts, they are prone to breakdown. A malfunction in any one of the numerous parts can soon transform a working marvel of technology into a standing monument of inefficiency.”

ACKNOWLEDGMENTS

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ASAE *see under* American Society of Agricultural Engineers

BSES *see under* Bureau Sugar Experimentation Stations

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COMMENTS

Q. Did you measure water use efficiency properly using the centre pivot?

A. We tried to but still we need to do more experiments as there has been a lot of variation.

Q. What is the potential area in Mauritius which is suitable to be irrigated using the centre pivot system?

A. I do not know what is the exact area. We need to bear in mind that this system cannot be used for areas with slopes exceeding 30 percent.