Table 1. Questionnaire used to quantify the adoption of irrigation scheduling in Pongola

Select scheduling method used on your farm - Tick one of the following:		
1	Intuition and/or own experience	
2	Use a rainfall delay rule (e.g. delay irrigation when rainfall is more than 15 mm)	
3	Wetting Front detector	
4	Tensiometers	
5	Capacitance Probes	
6	Neutron Probe	
7	Daily ET from Automatic Weather Station	
8	Soil Water Budget Calculation (profit and loss)	
9	Crop (Computer) Models	
10	Irrigation scheduling service provider	
11	Other: Specify	

In 2020, the total number of grower codes issued in Pongola was 204. This was used as the population size (N = 204). The sample size, denoting the number of responses received was 100 (n = 100), which amounts to 49% of the population and represented an area of 8 124 ha (total area = 16 796 ha).

In Table 1, Options 1 and 2 were counted as the non-adoption of irrigation scheduling tools and Options 3 to 10 were counted as adoption. Instances were encountered where more than one option was ticked. This was either due to farmers using different options on different fields (e.g. tensiometers on sprinkler fields and capacitance probes on drip and centre-pivot fields), or making use of an irrigation scheduling service provider, who made use of multiple technologies to provide the service (e.g. the Daily ET data from automatic weather stations, along with capacitance probe data were used in computer models to generate the scheduling advice). In each of these situations, only the most sophisticated/advanced scheduling option (of those presented) was used and counted for the analysis.

Results and Discussion

It must be highlighted upfront that the results presented in this paper are for a specific set of local conditions, in terms of the soil, planting date, crop variety, seasonal weather and irrigation system. The results are illustrative and reasonable variation can be expected under different conditions.

Irrigation applied

The rainfall received for the 12-month period (November to November) for the plant, third and fourth ratoon crops were 554, 675 and 639 mm, respectively. The average irrigation that is subsequently applied for each treatment is shown in Figure 2. The error bars in Figure 2 depicts the standard deviation. Substantial water savings were realised by all irrigation scheduling tools. In comparison to the fixed-cycle control treatment, irrigation was reduced, on average, by 38, 45 and 58% for the MyCanesim®, capacitance probe and the combined treatments, respectively.

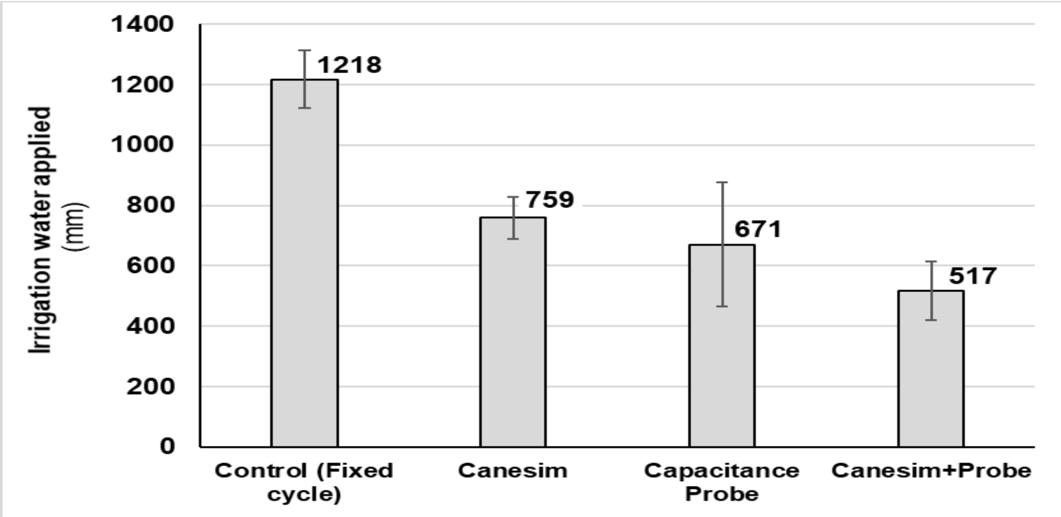

Figure 2. Irrigation water applied (averaged over three crops) for each scheduling method.

Sugarcane and RV yields

The sugarcane and RV yield data are presented in Figures 3a and 3b, respectively. The box and whisker plots present the minimum, first quartile, median, third quartile and maximum cane and RV yield values for each treatment across the three cropping seasons and five replications. The black dot and data labels in Figures 3a and 3b indicate the average cane and RV yield values.

As shown in Figure 3, the use of the irrigation scheduling tools also increased the sugarcane and RV yields. The sugarcane yield, on average, increased by 7.89 (7%), 11.76 (11%) and 10.89 (10%) tons/ha for the MyCanesim®, capacitance probe and the combined treatments, respectively. Similarly, the average RV yield improved over the control treatment by 1.07 (8%), 1.70 (13%) and 1.60 (12%) tons/ha.

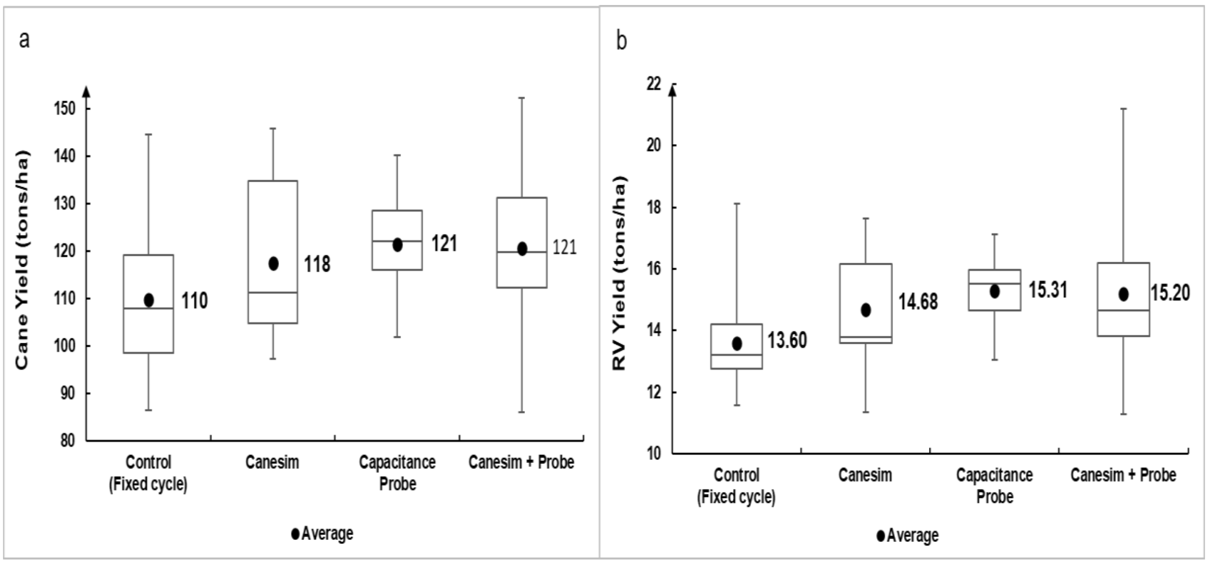

Figure 3. Cane (a) and RV (b) yield data achieved under each irrigation scheduling method

Irrigation water productivity

The Irrigation Water Productivity (IWP) is used to evaluate how much yield benefit was derived from every unit of irrigation water. The IWP, in terms of cane and RV yield, are shown in Figures 4a and 4b, respectively. IWP was expressed as tons of cane per hectare or tons of RV per hectare, per 100 mm irrigation water applied. The combined effect of yield improvement and reduced irrigation for the irrigation scheduling treatments resulted in a marked improvement in the IWP over the control treatment. The cane yield IWP was improved by 6.54 ton cane/ha/100 mm (73%), 10.51 ton cane/ha/100 mm (117%) and 14.94 ton cane/ha/100 mm (166%) for the MyCanesim®, capacitance probe and the combined treatments, respectively. Similarly, RV IWP increased by 0.82 (73%), 1.37 (123%) and 1.92 (172%) tons RV/ha/100 mm for each of the scheduling tools used for different treatments.

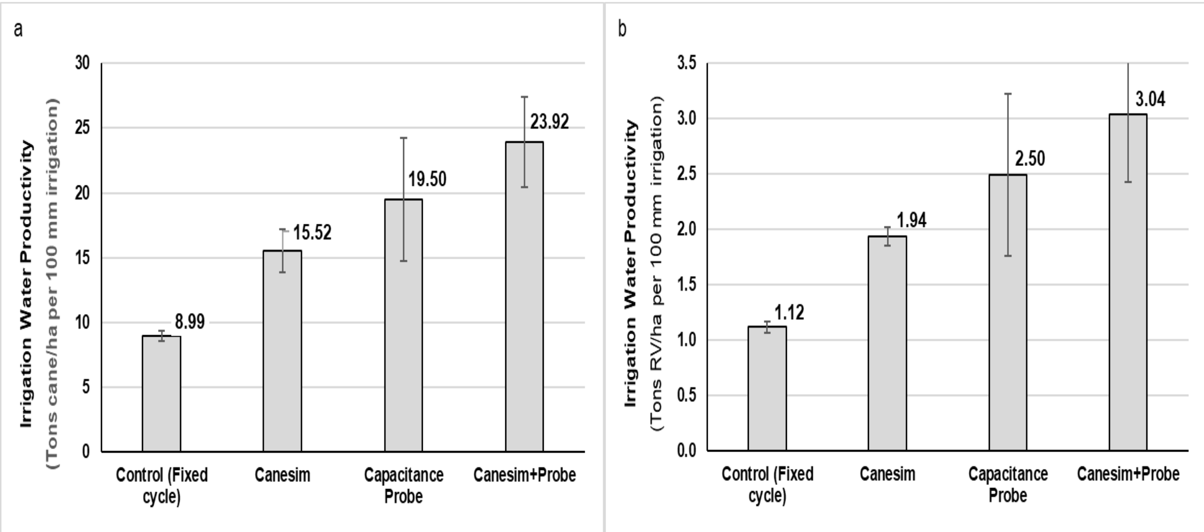

Figure 4. Irrigation water productivity in terms of (a) Cane Yield and (b) RV yield

Potential financial benefits of irrigation scheduling tools

Table 2. Financial benefits of irrigation scheduling tools: water and electricity cost savings and added income from RV yield increases above the control treatment

	Water Costs	Electricity Costs	Water + Electricity costs	Cost savings	RV gain	Extra Income from RV gain	Combined benefit (cost saving + RV gain)
	(R/ha)				(t/ha)	(R/ha)	(R/ha)
Control (Fixed cycle)	R2 774	R4 744	R7 518				
Canesim	R1 728	R3 207	R4 935	R2 583	1.1	R4 390	R6 973
Capacitance Probe	R1 529	R2 913	R4 442	R3 076	1.7	R6 962	R10 038
Canesim+Probe	R1 178	R2 398	R3 575	R3 943	1.6	R6 545	R10 487

Footnotes: Water costs = 22.78 c/m^3, Active electricity costs = R1.31 (2019 Landrate Tariff), RV pice = R 4086.26

The financial benefits derived from using the irrigation scheduling tools in this specific demonstration trial are shown in Table 2. The financial benefits include savings in water and electricity costs from reduced irrigation, as well as additional income from increases in the RV yield. Relative to the fixed-cycle control treatment, the average savings in water and electricity over the three seasons amounted to R2 583/ha (34%), R3 076/ha (41%) and R3 943/ha (51%)

for the MyCanesim®, capacitance probe and combined treatments, respectively. The financial benefit from the improved RV yield achieved with the irrigation scheduling methods amounted to R4 390/ha, R6 962/ha and R6 545/ha.

The combined financial benefits from using the irrigation scheduling tools (cost saving plus yield benefit) amounted to R6 973/ha, R10 038/ha and R10 487/ha for the MyCanesim®, capacitance probe and the combined treatments, respectively.

In this trial, we set out to demonstrate that the benefits of using the irrigation scheduling tools outweigh the cost of the tools, when compared to scheduling with a fixed cycle. By way of example, Figure 5 depicts the cost for the capacitance probe used in the trial, and which is commercially available in South Africa, relative to the benefits realised in the demonstration trial. The costs consisted of a once-off software fee, the cost for the probe hardware and an annual probe fee for maintenance and battery replacement. In practice, a probe is typically used to schedule 10 to 30 ha, depending on soil uniformity, or the field and irrigation block layout. Hence, the average annual benefit in R/ha reported in Table 2 must be multiplied by the number of hectares scheduled by the probe. In this example, we conservatively assumed that the probe is used to schedule a field of 10 ha.

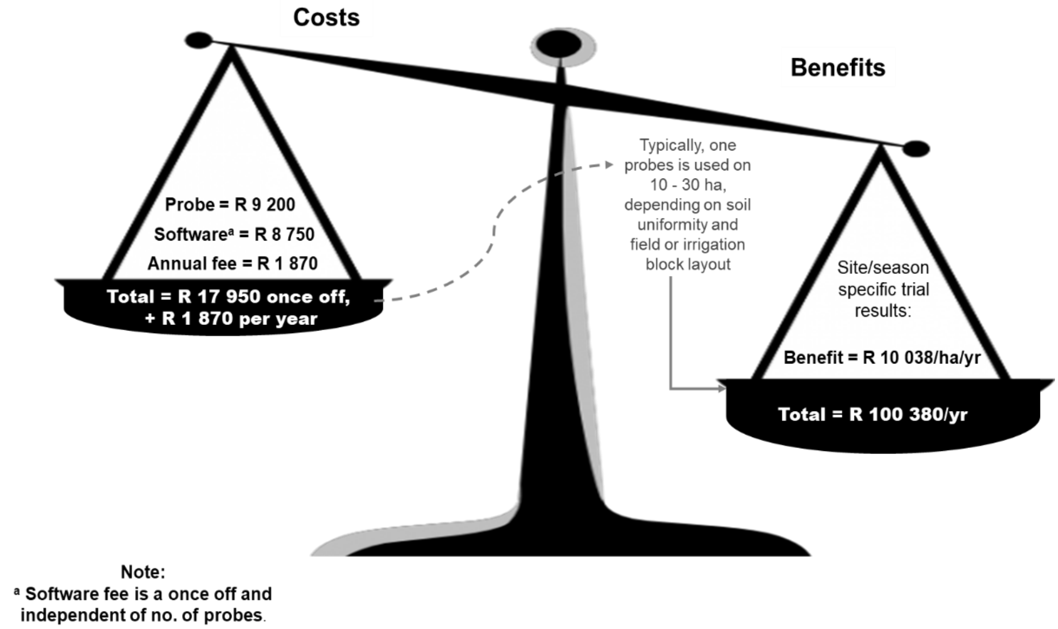

Figure 5. Cost and benefit of capacitance probes, compared to scheduling with a fixed-irrigation cycle

As shown in Figure 5, the benefits substantially outweigh the cost of scheduling with capacitance probes, when compared to scheduling with a fixed irrigation cycle. Based on the results of this trial, the combined financial benefit from 2 ha, in the first year, will cover the purchase and maintenance costs of capacitance probes in the first year. Thereafter, the annual probe fee will be covered by the financial benefit from just 0.19 ha. Alternatively, an RV yield increase of 0.49 tons/ha over the 10 ha area will cover the start-up costs in the first year and just 0.05 tons RV per ha (over 10 ha) for the annual maintenance cost in the subsequent years.

Adoption of irrigation scheduling tools

The irrigation scheduling adoption status was benchmarked by Jumman (2016) and is presented in Figure 6a. In 2014, only 11% of the sample (n = 111) adopted irrigation scheduling tools. The survey results in 2020, presented in Figure 6b, suggest that a substantial increase in adoption was realised. For the sample (n = 100), 65% of the respondents indicated adoption of irrigation scheduling tools.

In the context of promoting irrigation scheduling tools, it was important: (1) to obtain the trial results; (2) to demonstrate the benefit by translating the water savings and yield data into economic terms; and (3) to publicise the results via grower days and the published media. It is, however, difficult to establish the role of the demonstration trial, and the subsequent extension activities, in increasing the adoption of irrigation scheduling tools in Pongola. Many other factors have also played a role.

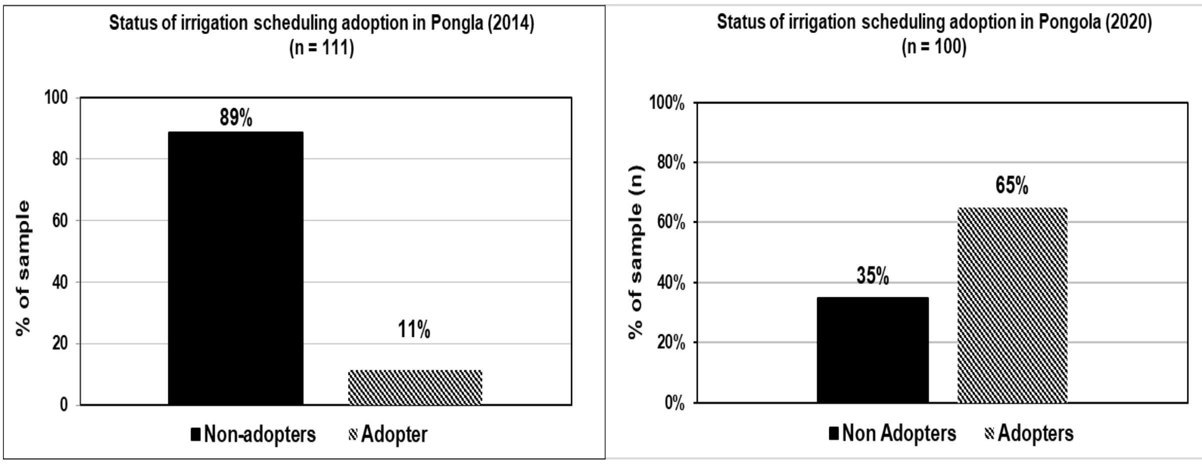

Figure 6. Adoption status of irrigation scheduling in Pongola in (a) 2014 (after Jumman, 2016) and (b) 2020

We hypothesise that some explanatory reasons for the adoption success in Pongola include:

- a rapid increase in electricity tariffs;
- the presence of extension in the region after a long period of no extension;
- a severe drought in the 2015 and 2016 seasons;
- increases in the water tariffs in 2018 and 2019;
- the advancement and popularity of probe technology and an increased presence and marketing effort of probe suppliers;
- a respected farmer in Pongola becoming an agent of an irrigation scheduling service provider (and his marketing efforts); and
- possibly the financial strain on the industry from sugar imports and the health promotion levy (sugar tax), which may have caused a decline in the profit margins, forcing farmers to manage their input costs, such as water and electricity, more carefully.

Finally, the distribution of the different irrigation scheduling methods used in Pongola is shown in Figure 7. Capacitance probes account for 52% of the sample (n=100). The non-adopter fraction (35%) consists of farmers who schedule according to their own intuition and experience

(22%) and/or subjective rainfall delay rules (13%). The irrigation scheduling service providers, who account for 9% of the sample, typically make use of a combination of capacitance probes, crop models and data from automatic weather stations and weather forecasts.

In the 2020 adoption survey, a few growers indicated that they used tensiometers as a cheaper option to use on semi-permanent sprinkler systems, while drip and centre-pivot systems were being scheduled with capacitance probes or service providers. Since these growers were using multiple options, only the most sophisticated tool (continuous monitoring, etc.) was counted, when processing the data from the questionnaire. For this reason, Figure 6 incorrectly suggests that there were no tensiometers in use in the sample.

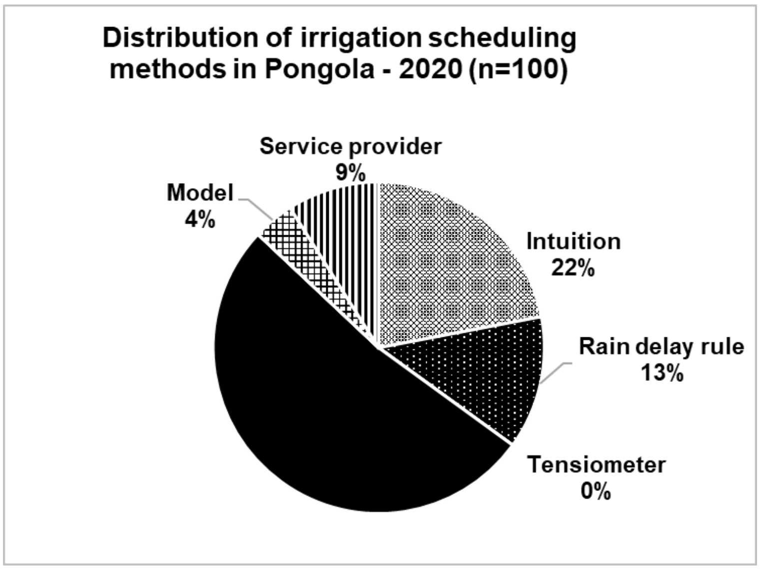

Figure 7. Distribution of irrigation scheduling methods in Pongola

More importantly, grower perceptions surfaced relating to the ease of implementing irrigation scheduling tools, in relation to different irrigation systems. It appears that their willingness to invest in scheduling tools is linked to the design and type of the irrigation system, in terms of flexibility and control. This was especially true for dragline and semi-permanent sprinkler systems, which were historically designed with long and less-flexible irrigation cycles. Growers perceived that the more modern and flexible irrigation systems, such as drip and centre-pivot systems, allow for more accurate scheduling. Therefore, we hypothesise that the adoption of more sophisticated irrigation scheduling tools is correlated with the type of irrigation system. This was a concern since semi-permanent sprinkler irrigation was still a dominant irrigation system in Pongola and accounted for 46% of the area under cane.

The adoption data presented in Figure 5 represents the non-adopters and adopters as a percentage of the grower sample, and it does not reflect the area. Hence, while many growers are scheduling irrigation on their drip and centre-pivot systems, which creates an impression of good adoption, it is possible that a larger area under the semi-permanent sprinkler systems is still not being scheduled objectively. Future work is therefore recommended: (1) to confirm the adoption status on semi-permanent sprinkler systems; and (2) to explore the ease or difficulty of using the current suite of available tools to beneficially schedule irrigation under semi-permanent sprinkler irrigation.

Conclusions

Although the results of this trial were site-specific, in relation to the soils and seasonal climatic conditions, the study clearly showed increased yields (7-12%) and a substantial reduction in the irrigation applications associated with the irrigation scheduling (38-58%) tools demonstrated. The combined value of improved yields, and water and electricity cost savings resulted in substantial financial benefits associated with using irrigation scheduling tools (R6 500-R10 500), compared to using a fixed irrigation cycle throughout the whole season.

Although the main objective of this trial was to demonstrate the benefits of using irrigation scheduling tools over fixed-cycle irrigation programs, the differences in the results from the three different scheduling techniques were apparent. The better improvement in yield, and especially in water use (cost saving), were associated with the increased sophistication of the scheduling technique used. The combination treatment, making use of irrigation simulation software with weather data and real time soil water data from a capacitance probe, proved to be the most successful method of irrigation scheduling for all parameters measured in this case study.

The results of this trial showed that if farmers moved away from a fixed irrigation cycle, the financial benefits of irrigation scheduling could cover the cost of the scheduling equipment and services, and it could improve the financial sustainability of producing sugarcane under irrigation. The start-up costs of capacitance probes, for example, could have been retrieved after the first year of implementation, from a small portion of the area (2 ha), relative to the area that is typically serviced (10 ha).

In addition to the direct financial benefits, using scheduling tools could have a number of indirect benefits, mainly due to a reduction in over-irrigation. These indirect benefits include limiting the loss of nutrients through leaching, limiting the build-up of undesirable salts in the soil, decreasing susceptibility to pests and diseases, as well as reducing water pollution.

Finally, a cross-sectional survey of 100 grower codes indicated that 65% of those fields/farms were making use of scientific irrigation scheduling, which suggests a substantial improvement from the 11% (n = 111) that were benchmarked in 2014.

ACKNOWLEDGEMENTS

Rodney Morgan, the farm manager of the Pongola Research Station, is acknowledged for managing the daily on-farm operations of the trial. The authors would also like to acknowledge Brendon Small, Etienne de Beer and Elbie Venter for enabling, and greatly assisting with, the adoption survey in 2020.

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