REFEREED PAPER

THE IMPACT OF IMPROVING IRRIGATION SCHEDULING FOR SMALLHOLDER GROWERS IN SWAZILAND

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Abstract

Smallholder sugarcane growers are essential in Swaziland for poverty alleviation and rural economic development. Total area under sugarcane in Swaziland is about 59 000 ha, with about 12 000 ha managed by a substantial number of smallholder growers (unpublished data[1]). Swaziland Sugar Association Technical Services conducted a study in 1998, which showed that smallholder growers did not follow any form of irrigation scheduling at all (unpublished data[2]). Irrigation scheduling is essential to meet crop water requirements and can help to reduce the cost of electricity use. This necessitated the initiation of an irrigation scheduling research project in 2011/12 funded by the European Union. At its inception, 63 growers from three sugarcane growing areas in Swaziland volunteered to participate. The pin-peg board irrigation scheduling method was used in the project because the smallholder growers could easily understand it. The pin-peg board method required growers to move a pin on a board on a daily basis depending on the day's evapotranspiration (ET). This method was combined with the profit and loss book, irrigation software programme (Canesched) and the cellular phone short message system technology to convey daily ET figures to growers, as well as receiving feedback from the growers. In addition, growers received training to enhance understanding and implementation of the project. Despite challenges, results showed that more than 80% of the smallholder growers participating in the project implemented the irrigation scheduling methods recommended. The growers received benefits such as improved yields and record keeping; and the project was rolled out to 67 new smallholder growers.

Keywords: Irrigation, smallholder-growers, scheduling, sugarcane, evapotranspiration

Background

The Swaziland sugar industry started in the 1950s at Big Bend (Ubombo), with one mill producing approximately 5600 metric tons (MT) of sugar per annum. The sugar industry has grown since then to three miller-cum-planters, Ubombo, Mhlume and Simunye. These three mills have an area of about 10 000 ha each. Lately, there has been a considerable increase in the number of smallholder growers, farming on about 1000 ha in the 1990s to about 12 900 ha, mostly on Swazi Nation Land. For the 2013/2014 season the total annual sugar production was approximately 653 000 MT from about 55 000 ha of sugarcane (unpublished

[1]Swaziland Sugar Association Integrated Annual Report 2013/14. 27 pp.
[2]Swaziland Sugar Association Extension Services. Irrigation Survey Report 1998. 15 pp.

data[3]). Since water constitutes a major constraint to increasing crop production, the needs of the growing population and developing national economies demand strengthening of water use for the purpose of increasing and stabilising agricultural production (Stewart and Nielsen, 1990).

Sugarcane is successfully grown under a wide range of temperature, solar radiation, rainfall, and soil conditions (Stewart and Nielsen, 1990). Sugarcane in Swaziland is mainly grown in the lowveld, which is a semi-arid area. Stewart and Nielsen, (1990) state that irrigation plays an essential role in the agricultural economy of drought-prone regions. The sugar industry is of critical importance to the development of Swaziland, and plays a multifaceted role in the economy (unpublished data[4]). Smallholder sugarcane growers are essential from the perspective of the national agenda for rural development and poverty reduction. The Swaziland government has established two smallholder development schemes: the Komati Downstream Development Project (KDDP) and the Lower Usuthu Sugarcane Project (LUSIP). The introduction by government of these two smallholder development schemes is seen as a catalyst for poverty alleviation in the rural population. It is expected that the number of smallholder schemes will double through an increase of about 8000 ha in area under sugarcane, most of which will be allocated to smallholders (unpublished data[5]). Sugarcane farming by smallholder growers is not only seen as a commercial activity where the growers maximise profits through efficient farming practices, but also as a development programme.

Sugarcane in Swaziland is grown under full irrigation mainly in the semi-arid lowveld, with rainfall contributing 20-25% of the crop water requirement. The remainder of the crop water requirement is supplied through irrigation. Irrigation accounts for about 15.4% of the sugar industry's production costs (unpublished data[6]). Basin flooding, furrow, sprinkler, drip and sub-irrigation by water table adjustment can be used to irrigate sugarcane (Stewart and Nielsen, 1990). Irrigation systems used in Swaziland to irrigate sugarcane are sprinkler (dragline, semi-solid and solid set), furrow, drip (surface and subsurface), centre pivot and floppy. Pressurised irrigation systems currently cover about 75% of the total area under production. About 90% of the smallholder growers use the pressurised irrigation systems. All the pressurised irrigation systems use electric water pumps of varying capacities.

The frequent occurrences of drought and increasing water demand for irrigation highlight the need for efficient management of water resources (unpublished data[3]). Unmeasured irrigation tends to waste water, nutrients and energy, and may cause soil degradation by waterlogging and salinisation (Stewart and Nielsen, 1990). Increasing water use efficiency is currently the focus of the sugar industry to improve competitiveness and to ensure sustainable utilisation of soil and water resources. Efficiency is generally understood to be a measure of the output obtainable from a given input (Stewart and Nielsen, 1990). The imminent implementation of the new Water Act, the decline in sugar prices, and the ever-increasing electricity and agricultural input costs all highlight the need to improve irrigation efficiency. Proper irrigation scheduling remains a key component in cost effective electricity use, leading to an improvement in smallholder incomes. For this reason the irrigation scheduling research project was identified as an ideal project for smallholder growers. The irrigation scheduling principle applied in the project is as defined by the American Society of Agricultural and

[3]Swaziland Sugar Association. Swaziland Crop Statistics 2013/14. 2 pp.
[4]MV Dlamini. Research proposal. Swaziland Sugar Association, Simunye. 2010. musavd@uniswa.sz/musavd@gmail.com
[5]Swaziland Sugar Association Integrated Annual Report 2012/13. 13 pp.
[6]Swaziland Sugar Association. Sugarcane Production Cost Index, 2015.

Biological Engineers (2009) and Stewart and Nielsen (1990). Stewart and Nielsen, (1990) define irrigation scheduling as the accurate forecasting of water application for optimal crop production. The American Society of Agricultural and Biological Engineers (2009) define it as the process of determining when to irrigate and how much water to apply, based on measurements or estimates of soil moisture or water used by the plant. Evapotranspiration (ET) was used to estimate the soil moisture or water used by the plant.

Based on the study conducted by Swaziland Sugar Association Technical Services (SSATS) in 1998, which showed that none of the smallholder growers followed any form of irrigation scheduling, the irrigation scheduling research project was initiated. Irrigation scheduling is a key element to proper management of irrigation systems (Stewart and Nielsen, 1990). The project focused on irrigation scheduling techniques and keeping records of irrigation, rainfall and other agronomic practices.

Stewart and Nielsen (1990) state that many irrigators fail to recognise the value of improved technical abilities to improve their agronomic and irrigation scheduling methods. They further stated that improved scheduling can either reduce irrigation costs and/or increase crop quantity or quality. Hence, Table 1 shows the three main objectives of the irrigation scheduling research project and strategies to achieve each objective thereof (unpublished data[3]).

Table 1. Project objectives and strategies.

Project objectives	Project strategy
To increase smallholder growers' understanding of irrigation scheduling.	By providing smallholder growers with relevant information regarding irrigation scheduling techniques for sugarcane. By assisting smallholder growers in learning how to effectively apply irrigation scheduling to improve the production and quality of sugarcane.
To effectively use smallholder grower collaborators as a major factor in helping farmers to learn irrigation scheduling.	By providing training programmes for smallholder growers that covers basic irrigation scheduling techniques.
To improve yields and quality of sugarcane for smallholder farmers.	By ensuring timely and correct application of water volumes during irrigation events.

The irrigation scheduling research project was effectively run for three growing seasons, from 2012/13 to 2014/15. The project was largely financed through the assistance of the European Union (EU). The total cost for the entire project period was 221 000 Euros.

Materials and Methods

Establishment of an office

To achieve the objectives of the project, an office was created at Swaziland Sugar Association Technical Services (SSATS). This was important for the provision of information on irrigation scheduling to participating smallholder growers through workshops, training courses and individual grower meetings. Also critical was the development of a training programme and supervised practical sessions for growers.

Selection of growers

Ronald *et al*. (1981) found that the requirements for integrating irrigation scheduling technology into a farming operation involves having sound methods, use of appropriate tools for the situation and working with a grower who has the proper attitude. Sixty-three participating growers from the three sugarcane growing areas in Swaziland (North 51%, South 46% and Central (Malkerns) 3%) voluntarily joined the project. Since the implementation of irrigation scheduling usually requires significant changes in overall farm operations, the grower must be willingly committed to the technology and have confidence in the personnel implementing the concepts (Ronald *et al*., 1981). In terms of mill group, 46% of the participating growers belonged to the Ubombo mill group, 33% belonged to the Mhlume mill group, and 21% belonged to the Simunye mill group.

Development of irrigation scheduling methods

Required tools and equipment such as vehicles, IT requirements and irrigation scheduling materials were purchased and distributed, and/or installed where applicable. There is a need to develop a relatively simple irrigation scheduling method suitable for on-farm scheduling for most of the farmers but still maintaining an acceptable level of accuracy (Darnell *et al*., 1981; Fereres *et al*., 1981). Hence, three irrigation scheduling methods suitable for the understanding of the smallholder growers were developed using locally available materials. The irrigation scheduling techniques used were the pin-peg board method, the Profit and Loss Book and the Canesched model. All the methods depended on meteorological data for the scheduling. Stewart and Nielsen (1990) confirm that monitoring the weather data can serve as an irrigation criterion in some situations. In principle, irrigation can be scheduled by monitoring the soil, the plant, and/or the microclimate (Stewart and Nielsen, 1990).

The pin-peg board is an irrigation scheduling tool. Figure 1 shows the pin-peg board that was produced and used for the project at SSATS. It is a method ideal for growers with little education. Growers move a pin on the board daily depending on the evapotranspiration (ET) to indicate a current soil moisture status. Other colour-coded pins were used to indicate dates on which irrigation and other agronomic practices were carried out. However, this method depended on the Profit and Loss Book to calculate the soil moisture content.

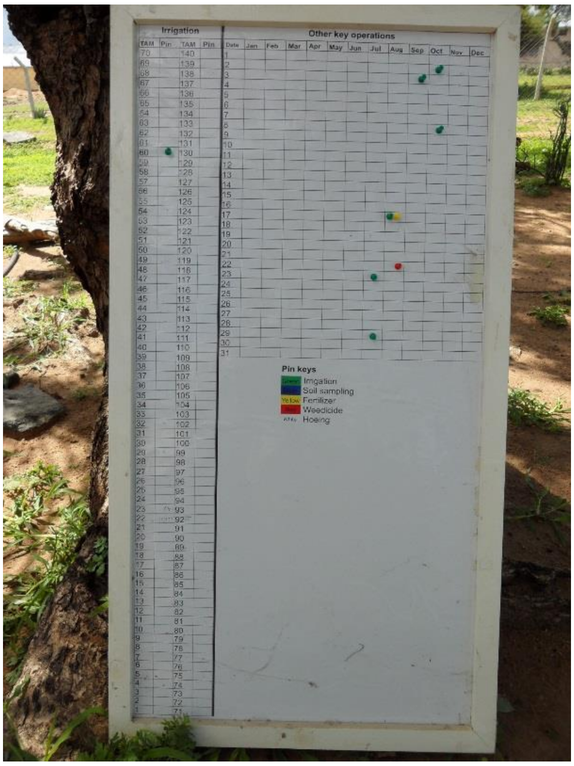

Figure 1. Pin-peg board irrigation scheduling method.

The Profit and Loss Book is a method commonly used in the Swaziland sugar industry to calculate or estimate soil moisture in the field using the total available moisture (TAM) of the soil, irrigation events, rainfall and the daily ET. The Profit and Loss Book is similar to the Water Budgeting and the Check-book methods. The Profit and Loss Book, similar to Water Budgeting, involves tracking the additions and losses to the area and maintaining a favourable soil level (http://www.agf.gov.bc/ca/resmgmt/publist/500series/577100-1.pdf). Similarly, the Check-book requires the farm manager to monitor the growth of the crop, use the daily ET, measure the rainfall or irrigation applied to the field, and calculate the new soil water deficit balance (http://www.extension.umn.edu/agriculture/water/irrigation-scheduling-checkbook-method/). The Profit and Loss Book format for the project was designed by SSATS. Two-quire notebooks with defined columns were used to calculate the soil moisture content. On the reverse of the Profit and Loss Book, a diary of events on the farm were recorded.

Canesched is a computerised method of irrigation scheduling developed by SSATS in the late 1990s. Like all computer irrigation scheduling programmes, Canesched maintains a water budget based on meteorological data, provides forecasts of water requirements, and estimates the appropriate time and amount of future irrigations (Stewart and Nielsen, 1990). Growers required basic computer skills in order to operate and use the Canesched programme.

At the end of the project the participants would select one or all of the irrigation scheduling techniques that they would find favourable and beneficial to them. Choice or success of any irrigation scheduling programme does not only depend on the adaptability and flexibility of the method and tools used, but is also directly related to the grower’s commitment to this technology and his confidence in his choice of personnel to implement the method (Ronald *et al*., 1981).

Information transfer

Regular communication with participants is imperative if irrigation scheduling is to be properly utilised (Ronald *et al*., 1981). This regular communication also allows the implementer to gain additional information and anticipate potential problems. A computerised short message system (SMS) technology to convey daily ET figures to growers as well as receiving feedback from the participating growers was installed. The SMS programme was able to send bulk SMS and to receive information through SMS from the participating growers. The SMS programme was also able to track and report on the sent SMS after every twelve hours from the time of sending. A backup programme was available if the SMS programme had problems, although the backup programme was not able to give the delivery reports.

The participating growers were issued with airtime on a monthly basis so that they could send irrigation, rainfall and agronomic records to the project office for advice and keeping; and for communicating with anyone regarding the progress of the project as well. The records received were utilised at the time of need and thereafter stored in the Canesched programme. Agronomic requirements are important, since their timing usually necessitates the use of a more long-range plan for irrigation scheduling (Ronald *et al*., 1981).

Smallholder growers received technical training and mentoring on the irrigation scheduling techniques through workshops, training courses and individual grower meetings during regular farm visits.

Collaborators
The first and most important collaborators were the smallholder growers. Each grower was a collaborator in the project and would in turn help other growers to start practising irrigation scheduling. Successful implementation of irrigation scheduling in agriculture production requires that scheduling be integrated into the overall farming operation (Ronald *et al*., 1981). The expectation was that, at the end of the project period, each grower would be fully conversant with the value, principles and practices of irrigation scheduling techniques which should in turn lead to measurable improvement in sugarcane production.

The second collaborator group was the Extension Officers employed by the Swaziland sugar industry to provide technical advice and support about the growing of sugarcane. An individual needs a solid educational background, an ability to communicate, and several years of experience if he is going to stand on his own as a competent irrigation scheduler. Successful implementation of irrigation scheduling is contingent upon the use of competent professionals (Ronald *et al*., 1981). The education background, experience and their involvement with smallholder growers were the basis upon which the Extension Officers were selected as collaborators. The professional irrigation collaborator who is implementing the technology must not only be capable, but must also have the full confidence of the grower (Ronald *et al*., 1981). The Extension Officers were first oriented and given their roles in the project. There were also periodical meetings to discuss progress and further improvement in supporting the project. Marvin and James (1981) confirm that Extension Agents should be trained and given assistance in developing and maintaining programmes for which they would be responsible.

Staff and administration of the project
The Project Management Team (PMT) administered the project and staff. The PMT included the Head of SSATS, Project Leader (SSATS Irrigation Engineer), Project Officer (SSATS Irrigation Officer), Field Officer, Project Clerk, Extension Officers and SSATS Finance Manager. The various PMT members at the operational, strategic and policy levels worked together to monitor the progress and impact of the project. The Project employed two full time staff members, the Field Officer and the Project Clerk.

Duration of the project
The project was first implemented in the mid-2011/12 season, and was effectively run for three growing seasons from 2012/13 to 2014/15, similar to a client development programme described by Ronald *et al*. (1981). The first year of implementation consisted primarily of gaining the growers' confidence and opening communications. The irrigation scheduling techniques were applied to only a portion of the farm. Entering the second year, the growers had a much higher level of confidence in the irrigation scheduling techniques. Scheduling began to expand to include other fields of the farm. The technology was fully implemented by the third year. It was at this point that irrigation scheduling techniques were spread to other growers. The project was formally evaluated at the end of each year.

Evaluation of the project
The overall project evaluation was the responsibility of the Project Officer under the directorship of the PMT. Two evaluation strategies were used to appraise the project. These were formative and summative evaluation. The summative (pre-project) evaluation began with the establishment of baseline data at the beginning of the project to assess the grower knowledge of irrigation scheduling practices. A questionnaire was developed to conduct the summative evaluation.

The formative evaluation was conducted through interviews and open-ended questionnaires. A monitoring and evaluation tool was developed to guarantee the systematic collection of information about the project operation and to provide the basis for sharing information with other similar projects. Periodic evaluations were carried out to assess the value of the irrigation scheduling techniques in helping participating growers to become effective schedulers, in order to improve their sugarcane production. Participating growers were asked about their day-to-day operations, the effectiveness of the training, their knowledge and implementation of the irrigation scheduling techniques, and other questions to provide feedback for the ongoing improvement of the operation of the project. The Project Officer met regularly with project staff to share findings from the formative evaluation efforts. Periodic reports on major findings of the formative evaluation were prepared and shared with the Swaziland sugar industry and international stakeholders.

Results and Discussion

Summative evaluation

Sixty-three growers voluntarily joined the project at its inception. However, the summative evaluation analysis showed results of 57 evaluated participating growers. Two of the participating growers resigned from the project, citing lack of time to concentrate on the research project. Evaluation could not be conducted with four other participating growers for various reasons.

Table 2 summarises the status of the evaluated participating growers before project implementation. The results showed that 84% of the evaluated participating growers did not practice any form of irrigation scheduling. Implementing any form of irrigation scheduling was difficult since the total available moisture (TAM) of their soils (75%) and the application rates of their irrigation systems were not known (68%). Beside the irrigation scheduling, 77% of the participating growers did not keep any records on their farms. Keeping of records is not only essential in practising irrigation scheduling but in farming as a whole.

Table 2. Status of the evaluated participating growers before the project implementation.

Pre-project status questions	Positive response (Yes%)	Negative response (No%)
Before the project, was there an irrigation scheduling method used in your farm?	16	84
Before the project, were there any irrigation records kept?	23	77
Before the project, was there a rain gauge?	70	30
Was the rainfall data recorded and kept?	37	63
If Yes, are there available records?	35	65
Before the project, did you know your TAM?	25	75
Before the project, did you know your irrigation system application?	32	68
Before the project, was there an auger?	7	93

Handling of rainfall before the project implementation

Although 70% of the evaluated participating growers had rain gauges, 63% of them were not keeping records of rainfall; yet the measurement of rainfall and irrigation amounts is essential to maintain water content for irrigation scheduling (Stewart and Nielsen, 1990). Nevertheless, 25% were using the rainfall for scheduling purposes as shown in Table 3. Eighteen per cent of the participating growers would stop irrigation if 30 mm of rainfall was received, and 15% would stop irrigation if 40 mm of rain fell. Only 5% of the participating growers did not use the rainfall information at all.

Table 3. How rainfall was used by the participating growers.

Waiting period before next irrigation	% growers using measurements
Rainfall was used for scheduling most of the time	25
They would stop irrigation if rainfall was 70 mm and above	2
They would stop irrigation if rainfall was 50 mm and above	5
They would stop irrigation if rainfall was 40 mm and above	15
They would stop irrigation if rainfall was 35 mm and above	5
They would stop irrigation if rainfall was 30 mm and above	18
They would stop irrigation if rainfall was 25 mm and above	5
They would stop irrigation if rainfall was 22 mm and above	2
They would stop irrigation if rainfall was 20 mm and above	10
They would stop irrigation if rainfall was 18 mm and above	3
They would stop irrigation if rainfall was 15 mm and above	5
Rainfall not considered at all	5

Table 4 shows how the participating growers that did not have rain gauges handled the rainfall moisture. Of the participating growers that did not have rain gauges, 53% would observe the soil surface to determine the need to stop irrigation. Eighteen per cent of the growers used a feel method, while 18% followed no particular pattern when rainfall was received. Twelve per cent of the growers relied on the amount of rainfall collected in their neighbour's rain gauge, yet rainfall should be measured for each scheduled field because amounts may be highly variable, even within 1 km (Stewart and Nielsen, 1990).

Table 4. Handling of rainfall moisture by participating growers who did not have rain gauges.

Method	% growers using method
Mere observation of the soil surface	53
Used the feel method	18
No particular pattern was followed	18
Used neighbour's rain gauge	12

Methods of scheduling irrigation used by the growers before the project implementation

Figure 2 shows that only 15.8% of the participating growers used the recommended irrigation scheduling techniques; where 10.5% were using Canesched and 5.3% were using the Profit and Loss book. As 84.2% of the participating growers did not follow any form of irrigation scheduling technique, Figure 2 also shows the other methods the growers used to estimate time of return to irrigate their fields. A larger portion (43.9%) of the participating growers opted to use the back-to-back (continuous/fixed cycle) irrigation method to irrigate their crop despite the fact that continuous irrigation frequently results in significant over-irrigation, particularly early and late in the season (Stewart and Nielsen, 1990). A more scientific feel method was used by 14% of the evaluated growers. Other growers observed the soil surface (21.1%) while 3.5% would guess the next irrigation event. Both methods had the potential to lead to either under-irrigation or over-irrigation. Only 1.8% would start irrigating when the nearby estate that practices irrigation scheduling had started to irrigate.

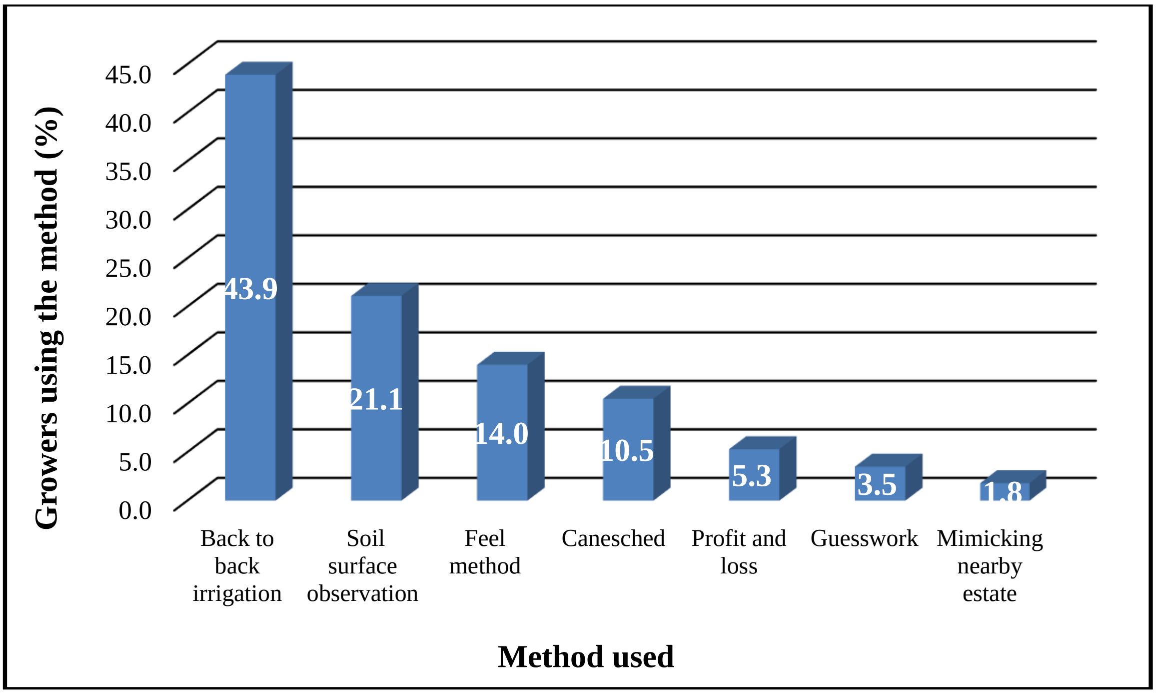

Figure 2. Form of scheduling irrigation used by the growers before the project implementation.

Tools used by the growers to check soil moisture

Since 93% of the participating growers did not have augers, 44% of the growers used spades to check soil moisture as shown in Table 5. Growers that used smut hoes, sticks and hoes were 5% each. The growers were even using sampling augers (3%) to check water content in the soil. One per cent of the growers would borrow Dutch augers while the other 1% each would use bush knives and metal rods to check soil moisture. Only 7% had a Dutch auger, which is a relevant tool of digging to check the soil moisture. About 25% of the participating growers were not checking the soil moisture at all.

Table 5. Tools used by the participating growers to check soil moisture.

Methods of checking soil moisture	Growers using the method (%)
Spades	44.0
Smut hoes	5.0
Sticks	5.0
Hoes	5.0
Picks	3.0
Sampling augers	3.0
Bush knives	1.0
Metal rods	1.0
Borrowed augers	1.0
Dutch augers	7.0
Not checked	25.0

Formative evaluation

The formative evaluation was conducted and analysed for the three successive harvesting seasons of 2011/12 to 2013/14. Table 6 shows the types of records that were kept by the participating growers. At the start of the project the most prevalent records kept by the participating growers were harvesting records. There were 21% of the participating growers that did not keep any record at all on their farms at the inception of the project. The impact of the project resulted in all of the participating growers keeping some record. The improvement was substantial. The number of participating growers keeping harvesting records improved from 47% in 2011/12 to a maximum of 98% in the 2013/14 season. The improvement in record keeping by the growers will assist in achieving the first objective. In order for the growers to increase their understanding of irrigation scheduling, keeping of records is essential.

Table 6. Records kept by the participating growers.

Type of record kept	% growers keeping records		
	2011/12	2012/13	2013/14
Harvesting	47	89	98
Finances	26	75	93
Fertilisers	26	89	89
Smut roguing	23	56	61
Herbicides	23	84	89
Weeding	12	76	80
Soil sampling	5	69	75
Planting	5	71	61
Labour	4	84	89
Electricity	2	80	84
Annual plan	2	31	30
Time book	2	75	75
Verging	2	58	57
Mowing	2	36	43
Stock taking	2	40	57
Ripening	2	55	61
Water order	2	40	45
Training records	-	-	30
Telephone bills	-	-	39
Disciplinary records	-	-	52
Uniform records	-	-	79
Contract records	-	-	63
Swaziland National Provident Fund records	-	-	71
VAT payments	-	-	96
None	21	0	0

Provision of information

The first objective would be achieved by providing smallholder growers with relevant information regarding irrigation scheduling techniques for sugarcane. Actual daily ET values were sent to the participating growers. Table 7 shows that by 2013/14 all the participating growers received information sent from the project office. Project field records sent to SSATS at least once a month improved from 49% in the 2012/13 season to 59% in the 2013/14 season. Although there was improvement in the information sent by growers, there is still a challenge for the participating growers to effectively send information to the project office.

Table 7. Reception of the information by participating growers from the project office.

Data verification	Reception (%)	
	2012/13	2013/14
Are ET values from SSATS received at least once a week?	95	100
Is the airtime issued by SSATS received?	93	100
Are project field records sent to SSATS at least once a month?	49	59

Irrigation scheduling techniques usage

To determine the understanding of the irrigation scheduling techniques, the smallholder growers were evaluated to check their usage of the irrigation scheduling techniques. Figure 3 shows that in the 2011/12 season about 83% and in the 2012/13 season about 75% of the participating growers preferred the pin-peg board method. This is because it is a simple and user-friendly irrigation scheduling technique. However, due to the ongoing trainings, growers began to gain confidence in using the profit and loss book. Hence, in 2013/14 season the profit and loss book was the preferred method. Canesched was the least used method (<20%) because Canesched depends on availability of a compatible computer on the farm and a higher level of computer skills. These factors limited the adoption of this irrigation scheduling technique. Ronald *et al*. (1981) suggest that for a computerised irrigation scheduling system to be truly successful, it must be integrated into the total farming operation.

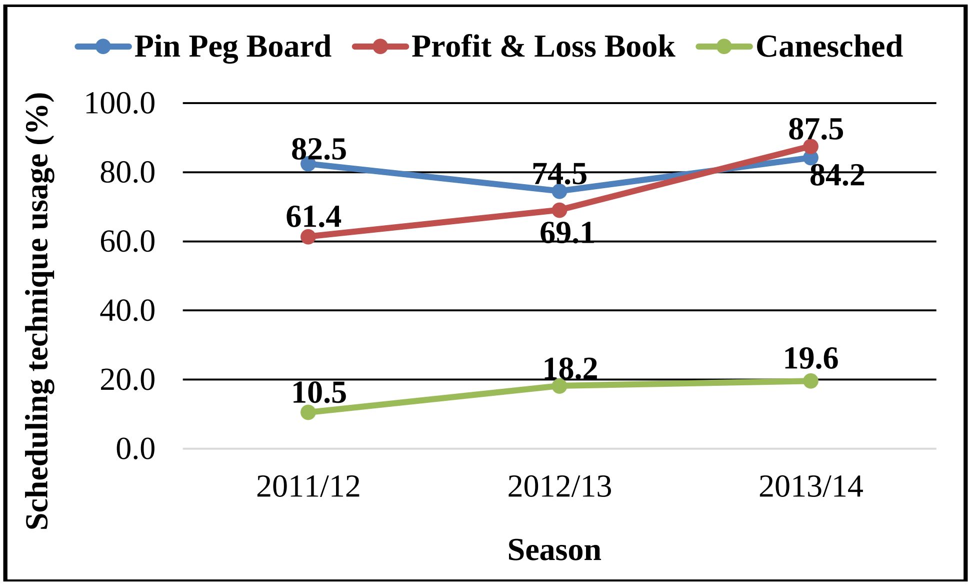

Figure 3. Usage of irrigation scheduling techniques by participating growers.

Impact of collaborators

To achieve the second objective, the smallholder growers were provided with training programmes that covered basic irrigation scheduling techniques. Table 8 shows attendance and value as perceived by the participating growers to training workshops organised by SSATS. A training workshop per year was held in 2011 and 2012. The participating growers were first trained as one group in 2011. Subsequently, three training events were conducted in 2012 in their three respective areas. In 2013, the focus was on farm visits to assist participating growers on a needs basis. All the participating growers attended the training workshops. Sixty-one per cent of the growers were able to send at least two representatives per grower. In addition, 77% of the attendees were in a supervisory role, which gave the project an advantage of direct influence on the farm. Furthermore, the 2012 workshop (81%) was of great value to the participating growers when compared with 2011 (38%). This was because the participating growers were trained in groups in their respective areas in 2012, whereas in 2011 they were trained as one big group.

Table 8. Attendance of the project's workshops by the participating growers.

Item	Details	Attendees (%)
Total number of people who attended the workshops per grower	All courses not attended	0
	At least one person attended	23
	Two people attended	61
	Three people attended	14
	Four people attended	2
	Five or more people attended	0
Roles of attendees on the farm	Farm Supervisor/Manager/Sole owner	77
	Management committee	28
	Team leader/Indvuna	26
	Irrigator	12
	Farm Clerk/Secretary	26
	Other	7
Benefit received from the first workshop in November 2011	No help	7
	Little help	55
	Great help	38
Benefit received from the second workshop in June 2012	No help	2
	Little help	15
	Great help	81

Although the training programmes were conducted using the local language (Siswati, which all of them understood), most of the irrigation scheduling requirements are in English. For that reason, the participating growers were evaluated to check their level of education. This would also have an impact when practising any adopted irrigation scheduling technique. Figure 4 shows that more than 60% of the officers responsible for implementing the projects at the participating growers' farms have reached the high school level. The high school level of education is ideal for the participating growers to use all the irrigation scheduling techniques and acts as an advantage in sharing the irrigation scheduling information with their neighbours. There were only 2% uneducated participants for the 2011/12 season, while in the evaluation conducted for the 2012/13 and 2013/14 season everyone had some level of education. The improvement in the level of education was not due to furthering of studies, but because 2% of the responsible officers had resigned.

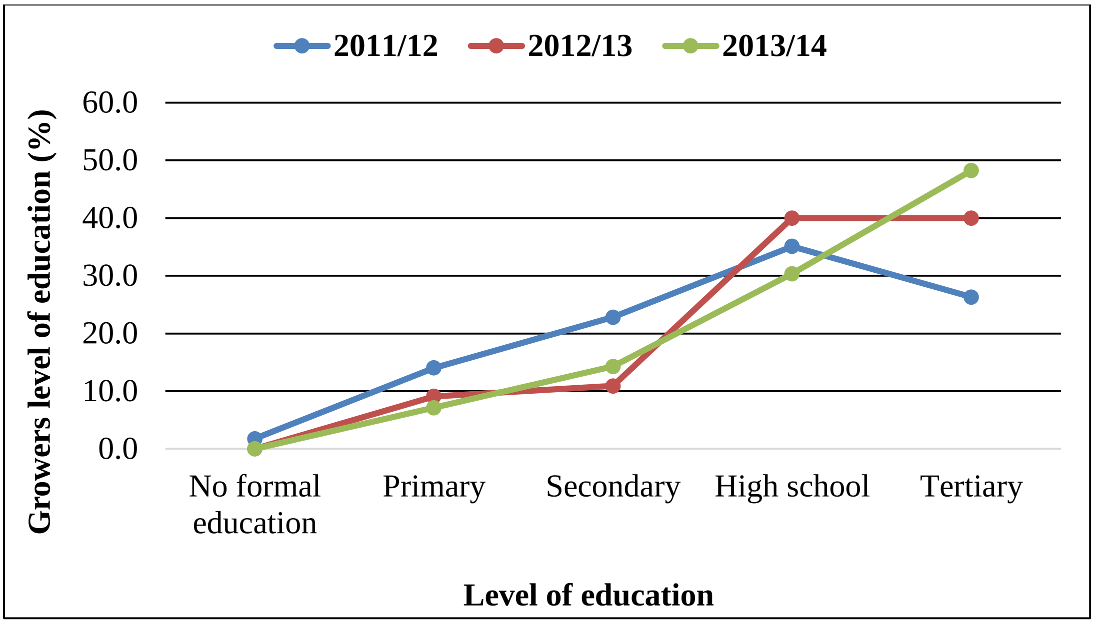

Figure 4. Level of education of the responsible officers in the project.

The most important collaborators were the smallholder growers. Marvin and James (1981) stated that irrigation scheduling activities were initiated with innovators to identify specific savings and yield benefits. Their testimonials were then used to influence early adopters. The project started with 63 volunteers who were used to influence other growers to adopt the irrigation scheduling techniques. The second collaborators were the Extension Officers who provided the technical advice and support about the growing of sugarcane. Marvin and James (1981) stated that country Extension Agents were trained and given assistance in developing and maintaining irrigation scheduling programmes for which they were responsible. Successful adoption requires that promoters understand social issues, as technology transfer is affected by human behaviour (Marvin and James, 1981). The Extension Officers were capacitated on how to support the growers in the project. Due to the wide scope of Extension Officers in dealing with sugarcane growers, they were able to deal with social issues which could have hindered adoption of the irrigation scheduling techniques. Through the assistance of the collaborators, the project was rolled out to 67 new growers. Two training sessions have also been conducted with these new growers. The first one, the project was introduced to the growers as one group. Subsequent training sessions were divided into smaller groups called zones, where the growers in each zone were encouraged to assist their neighbours. The new growers would then become part of the project just like the growers who joined the project at its inception.

Cane yields

One of the main objectives of the project was to improve yields and quality of sugarcane for smallholder farmers. The general goal of most producers is to maximise yield (Stewart and Nielsen, 1990). This goal was to influence the type of management and scheduling strategies that a grower might implement. Yields were analysed to determine the impact of the project in production terms. Figure 5 shows that project fields that used the irrigation scheduling methods performed better in tons cane per hectare (TCH) than the average smallholder (small-scale grower) in the three years from 2012/13 to 2014/15. Project fields performed 2.3, 0.8 and 0.7% higher than average smallholder yields in 2012/13, 2013/14 and 2014/15, respectively. Although the performance was still lower than the average for the whole sugar industry (including medium-scale and large-scale growers), the results suggest that implementing irrigation scheduling methods improved tons cane per hectare for the participating growers. The decrease in yields from 2013/14 to 2014/15 were felt over the whole sugar industry due to unfavourable climatic conditions.

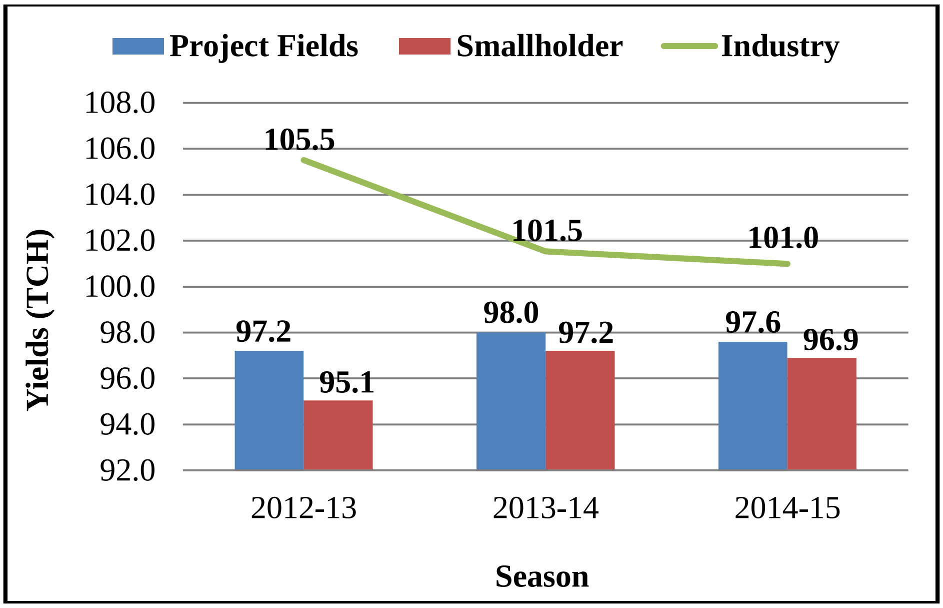

Figure 5. Yield results in tons cane per hectare (TCH) from project fields compared with smallholder and whole industry performance.

Cane quality

The amount of sucrose in cane is generally considered a reasonable indicator of quality. Sucrose from the project fields was compared with the rest of the smallholder growers and the whole industry. The results showed that the tons sucrose per hectare (TSH) was 2.8, 1.6 and 1.2% higher in the project fields in 2012/13, 2013/14 and 2014/15, respectively, when compared to the smallholder average performance as shown in Figure 6.

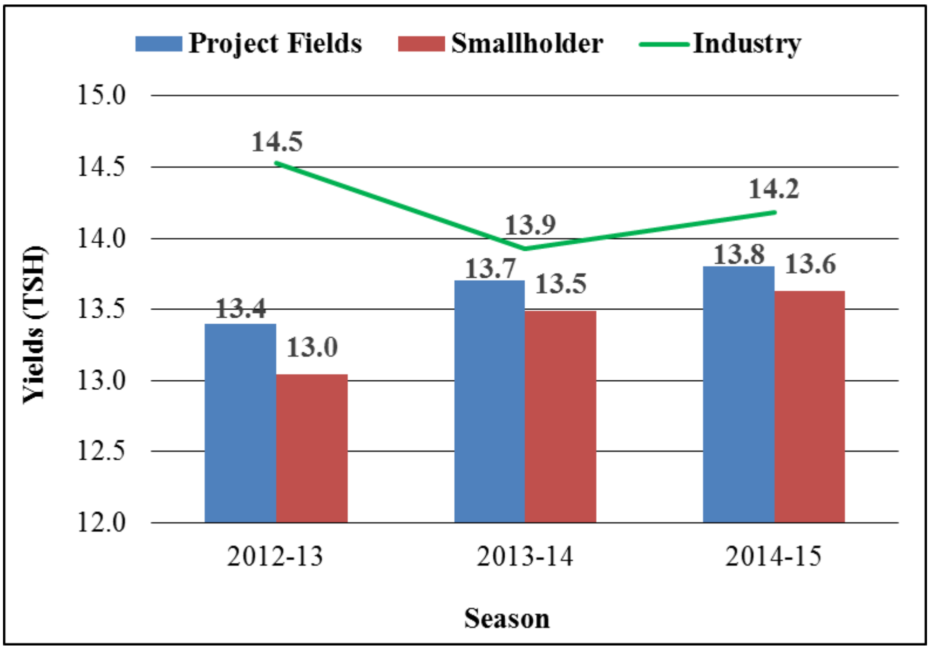

Figure 6. Yield results in tons sucrose per hectare (TSH) from project fields compared with smallholder and whole industry performance.

Correct irrigation water volumes were applied timeously during irrigation events on the project fields of the participating growers. This practice could have had a positive impact in the yield increases as it appeared to be case in the three consecutive years of implementing the irrigation scheduling tools.

Other results
Eighty-nine per cent of the rain gauges were installed within the field vicinity by the participating growers. Rainfall should be measured for each scheduled field because amounts may be highly variable, even within 1 km (Stewart and Nielsen, 1990). Others could not install them within the field vicinity because of theft and vandalism. Eighty-four per cent of the participating growers were correctly keeping records of the rainfall received. One major opportunity for reduced pumping hours is through better use of rainfall. Through effective irrigation scheduling, opportunities to switch off when rainfall occurs can be maximised thus reducing the amount of irrigation water pumped, and through that, reducing energy use.

The distributed soil augers were used by 59% of the participating growers to measure soil moisture in their fields as part of the project. All these interventions assisted the growers in better managing their irrigation scheduling.

The project also stimulated the participating growers to engage in other positive initiatives on their farms. These include the introduction of record keeping systems, motivation to identify soil characteristics of the fields and determination of application rates of the irrigation systems, and interest in the evaluation of irrigation systems to determine current performance status.

Conclusions

Overall, the project was a success in the three years of implementation regardless of some challenges. The following conclusions drawn from all the evaluated participating growers:

Increasing the smallholder growers' understanding of irrigation scheduling
More than 80% of the smallholder growers participating in the project implemented the irrigation scheduling methods. All the participating growers received information sent from the project office. Growers who in the past did not keep any form of irrigation and rainfall records were now keeping them, as well as records of other farming activities.

The effective use of smallholder growers collaborators as a major factor in helping other growers to learn irrigation scheduling
The project was rolled out to 67 new growers through the assistance of the participating growers and Extension Officers. Training programmes for smallholder growers covering basic irrigation scheduling techniques were provided. All the growers attended all the planned training sessions.

Improvement in yields and quality of sugarcane for smallholder growers
Although on average the sugarcane yields (TCH) and sucrose quality (TSH) of the project fields were higher than the average smallholder yields in the three consecutive years of implementing the irrigation scheduling tools, the improvement was not proved scientifically to be a direct contribution of the project implementation.

Recommendations

It is recommended that a detailed study and analysis of electricity and water use be done to quantify the impact of the project on savings due to irrigation scheduling.

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REFERENCES

American Society of Agricultural and Biological Engineers (2009). ASABE Standards 2009. *Standard Engineering Practices Data.* 1114 pp.

Darnell RL, Earl CS and Hal DW (1981). Irrigation scheduling by the checkbook method. Proceedings of the American Society of Agricultural Engineers Irrigation Scheduling Conference, December 1981: 187-188.

Fereres E, Goldfien RE, Pruitt WO, Henderson DW and Hagan RM (1981). The irrigation management program: A new approach to computer assisted irrigation scheduling. Proceedings of the American Society of Agricultural Engineers Irrigation Scheduling Conference, December 1981: 202-206.

Marvin NS and James V (1981). Twenty-five years of modern irrigation scheduling promotional efforts. Proceedings of the American Society of Agricultural Engineers Irrigation Scheduling Conference, December 1981: 202-206.

Ronald JB, Gary LJ and Gary DJ (1981). Successful implementation of computerized irrigation scheduling. Proceedings of the American Society of Agricultural Engineers Irrigation Scheduling Conference, December 1981: 213-218.

Stewart BA and Nielsen DR (1990). *Irrigation of Agricultural Crops.* Madison, Wisconsin USA. pp 5-29, 509-533, 835-852.