Increasing sugarcane yields and decreasing inputs for smallholder growers through improvements in irrigation scheduling in Swaziland

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Abstract Smallholder sugarcane growing is essential in Swaziland for poverty alleviation and rural economic development. The area under sugarcane in Swaziland is about 59 000 ha, with about 14 000 ha managed by a large number of smallholder growers. The Swaziland Sugar Association Technical Services conducted a study in 1998 that showed that smallholder growers did not follow any form of irrigation scheduling. Irrigation scheduling is essential to meet crop-water requirements and can help to reduce the cost of electricity usage. This observation led to the initiation of an irrigation scheduling research project in 2011/12 funded by the European Union. At its inception, 63 growers from the 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’, the irrigation scheduling software ‘Canesched’ and the cellular phone short message system technology to convey daily ET figures to growers and to receive feedback from them. In addition, growers received training to enhance their understanding and implementation of the project. Overall, the project was a success in the 4 years of implementation despite some challenges. More than 80% of the smallholder growers participating in the project implemented the irrigation scheduling methods. The growers benefited by up to about 21% and 30% savings in water and electricity, respectively, and also through improved record keeping. Observed trends showed an improvement of about 2% in yields and 4% in cane quality. Overall, the project was a success as there were water and electricity savings and increased yields. The project has subsequently been rolled-out to 79 further smallholder growers.

Key words Irrigation scheduling, smallholder, growers, project, sugarcane

INTRODUCTION

Sugarcane is grown successfully worldwide under a wide range of temperature, solar radiation, rainfall, and soil conditions (Jones et al. 1990). In Swaziland, sugarcane is grown mainly in the semi-arid Lowveld with access to full irrigation and rainfall contributing about 24% of the crop water requirement (Swaziland Sugar Association Integrated Annual Report 2015/16, unpublished data). Irrigation accounts for about 15.4% of the sugar industry’s production costs (Swaziland Sugar Association Sugarcane Production Cost Index, 2015, unpublished data). Hillel (1990) indicated that irrigation plays an essential role in the agricultural economy of drought-prone regions, with basin flooding, furrow, sprinkler, drip and sub-irrigation by water-table adjustment highlighted as options to irrigate sugarcane. 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 pressurised irrigation systems. All these pressurized irrigation systems use electrical 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. Unmeasured irrigation tends to waste water, nutrients, and energy, and may cause soil degradation by waterlogging and salinization (Hillel 1990). Increasing water-use efficiency is currently the focus of the sugar industry to improve competitiveness and to ensure the sustainable utilization of soil and water resources. The imminent implementation of a new Water Act, decline in sugar prices, and the ongoing increases in costs of electricity and agricultural inputs all highlight the need to improve irrigation efficiency. Proper irrigation scheduling remains a key component of cost effective electricity use leading to an improvement in smallholders’ incomes. It was for this reason that 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 Biological Engineers (2009) and Heermann et al. (1990). In particular, Heermann et al. (1990) define irrigation scheduling as the accurate forecasting of water application for optimal crop production, whereas the American Society of Agricultural and Biological Engineers define it as the process of determining when to irrigate and how much water to apply, based upon measurements or estimates of soil moisture or water used by the plant.

Based on a study conducted by Swaziland Sugar Association Technical Services (SSATS) in 1998 that showed that none of the smallholder growers followed any form of irrigation scheduling, the irrigation scheduling research project was initiated. Irrigation scheduling is important in proper management of irrigation systems (Heermann et al. 1990), and improved irrigation scheduling may either reduce irrigation costs and/or increase crop quantity or quality. Our irrigation scheduling research project focused on the irrigation scheduling techniques and keeping records of irrigation, rainfall and other agronomic practices to achieve each of the three main objectives, through appropriate strategies (Table 1).

Table 1. Project objectives and strategies.

<table>
<thead>
<tr>
<th>Project objective</th>
<th>Project strategy</th>
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<tbody>
<tr>
<td>1. To increase smallholder growers’ understanding of irrigation scheduling</td>
<td>- By providing smallholder growers with relevant information regarding irrigation scheduling techniques for sugarcane</td>
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<td></td>
<td>- By assisting smallholder growers in learning how to effectively apply irrigation scheduling to improve the production and quality of sugarcane</td>
</tr>
<tr>
<td>2. To effectively use smallholder grower collaborators as a major factor in helping growers to learn irrigation scheduling</td>
<td>- By providing training programmes for smallholder growers that cover basic irrigation scheduling techniques</td>
</tr>
<tr>
<td>3. To improve yields and quality of sugarcane for smallholder growers</td>
<td>- By ensuring timely and correct application of water volumes during irrigation events</td>
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MATERIALS AND METHODS

Establishment of an office and programmes

In order to achieve the objectives of the project, a dedicated project office was established at SSATS. Its role was to provide 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) observed 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, since the implementation of irrigation scheduling usually requires significant changes in overall farm operations. Sixty-three participating growers from the three sugarcane-growing areas in Swaziland (North, Central and South) voluntarily joined the project.

Development of irrigation scheduling methods

Required tools and equipment such as vehicles, IT equipment, and irrigation scheduling methods materials were purchased and distributed, and/or installed where applicable. Darnell et al. (1981) and Fereres et al. (1981) indicate that there is a need to develop a relatively simple irrigation scheduling method suitable for on-farm scheduling for most of the growers, but still maintain an acceptable level of accuracy. Hence, we developed three irrigation scheduling methods suitable for smallholder growers using locally available materials. The irrigation scheduling techniques used were the 'Pin-peg board'
method, the ‘Profit and loss book’, and ‘Canesched’. All of these methods are described below and are dependent on meteorological data for scheduling.

The Pin-peg board (Fig. 1) is an irrigation scheduling method designed by 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 current soil moisture status. Evapotranspiration is calculated using irrigation scheduling software as indicated below. Colour-coded pins are used to indicate dates on which irrigation and other agronomic practices are carried out. However, this method is depended on the Profit and loss book to calculate the soil moisture content. Therefore, this method is only a simplified extension of the Profit and Loss book method.

![Pin-peg board irrigation scheduling method.](image)

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 water (TAW) of the soil, irrigation events, rainfall and the daily ET. It is similar to the ‘Water budgeting’ and ‘Check-book’ method (Darnell et al. 1981). The Profit and loss book, as with the Water budgeting and Check-book involves tracking the additions and losses of soil water, and maintaining a favourable soil water level. The Profit and loss book format for the project was designed by SSATS.

Canesched is a computerized method of irrigation scheduling developed by SSATS in the late 1990s using the CANEGRO model principles. CANEGRO is a simulation model that is used to estimate ET (McGlinchey and Inman-Bamber 2002). Canesched, like all other computer irrigation scheduling programs, maintains a water budget based on meteorological data, provides forecasts of water requirements, and estimates the appropriate time and amount of future irrigations. Growers required basic computer skills in order to operate and use the Canesched programme.

At the end of the project, the participants were expected to select one or all of the irrigation scheduling techniques that they found favourable and/or beneficial. Choice or success of any irrigation scheduling program depended not only on the adaptability and flexibility of the method and tools used, but is also directly related to the grower’s commitment to the technology and his confidence in the personnel implementing the method (Ronald et al. 1981).
Calculation of evapotranspiration

Evapotranspiration was used to estimate the soil moisture or water used by the plant. The ET estimate that was sent to the participating growers was calculated using the Canesched software. Canesched estimated the ET using the meteorological data sourced from four meteorological stations located in the sugarcane growing regions of Swaziland. Most of the ET used in the Swaziland sugar industry is derived from the CANEGRO model principles (McGlinchey and Inman-Bamber 2002). Canesched just like CANEGRO calculates ET using the Penman-Monteith equation in a modified two-step energy balance (McGlinchey and Inman-Bamber, 1996). McGlinchey and Inman-Bamber, (2002) found that CANEGRO estimation of ET was within an acceptable degree of accuracy. The following version of the Penman-Monteith equation is used in Canesched to calculate ET:

\[ \hat{ET} = \Delta (R_n - G) + pc_p(\varepsilon_a - \varepsilon_d)/r_a \]

\[ \Delta + y(1 + r_a/r_s) \]

where \( \hat{ET} \) is the vapour flux density (MJ/m\(^2\)/d), \( \Delta \) is the slope of saturated vapour pressure-temperature curve (kPa/ºC), \( R_n \) is net radiation flux density to the plant canopy (MJ/m\(^2\)/d), \( G \) is the soil heat flux (MJ/m\(^2\)/d) = 0.21(Ti - Ti-1) where Ti is mean air temperature on the ith day (Smith 1992), p is the density of air (kg/m\(^3\)), \( c_p \) is the specific heat of air (MJ/kg/ ºC, \( \varepsilon_a \) and \( \varepsilon_d \) are the saturated and measured vapour pressures of the air (kPa), y is the psychometric constant for unsaturated conditions, \( r_s \) is surface resistance to vapour transfer (s/m), \( r_a \) is the average daily aerodynamic resistance to vapour and heat diffusion (s/m).

Information transfer

Regular communication with participants is imperative if irrigation scheduling is to be properly utilized (Ronald et al. 1981). A computerized 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 SMSs and to receive information through SMSs from the participating growers. The SMS programme was also able to track and report on the sent SMSs. A backup programme was also available if the SMS programme had problems, although the backup programme could not 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 record-keeping, as well as for communicating with anyone regarding the progress of the project. The records received were utilized when needed and stored in the Canesched programme.

Smallholder growers received technical training and mentoring on the irrigation scheduling techniques. The training and mentoring occurred 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. The expectation was that at the end of the project period, each grower would be fully conversant with the value, principles and practices of the irrigation scheduling techniques that would in turn lead to measurable improvement in sugarcane production.

Ronald et al. (1981) state that successful implementation of irrigation scheduling is contingent upon the use of competent professionals. The second group of collaborators were the extension officers employed by the Swaziland sugar industry to provide technical advice and support about growing sugarcane. Their educational background, experience and involvement with smallholder growers were the bases for their selection as collaborators. Ronald et al. (1981) also state that a professional irrigation collaborator who is implementing the technology must not only be capable, but must also have the full confidence of growers. The extension officers were inducted initially and given their roles in the project. There were also periodic meetings to discuss progress and further improvement in supporting the project.
Staff and administration of the project

The Project Management Team (PMT) administered the project and staff. The various PMT members at the operational, strategic and policy levels worked together to monitor the progress and impact of the project. The project included two full-time staff members, a project field officer and a project clerk.

Duration of the project

The project covered four growing seasons from 2012/13 to 2015/16. The first year of implementation consisted primarily of gaining the growers’ confidence and initiating communication. The irrigation scheduling techniques were applied to only a portion of each participating farm. Entering the second year, the growers had a much higher level of confidence in the irrigation scheduling techniques, and began to expand their involvement by including other fields of their farms.

Evaluation of the project

The project was evaluated formally at the end of each year. 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 evaluations. The summative (pre-project) evaluation began with the establishment of baseline data at the beginning of the project to assess the growers’ knowledge of the irrigation scheduling practices. A questionnaire was developed to conduct the summative evaluation.

The formative evaluation was conducted through interviews and open-ended questionnaires. 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.

As there were logistic challenges, the yield performance was not subjected to ideal research methods and statistical analysis; but the yield performance was compared using the yield outcome that was obtained from the Swaziland Sugar Industry Data Base (SSIDB). The project fields (where irrigation scheduling methods were used) were compared with the other fields of the participating grower where the irrigation scheduling methods were not used. Participating growers applied the same agronomic practices both in project fields and in all their other fields. Although soil effects were not considered in the comparison, the project fields were randomly selected by the participating growers.

RESULTS AND DISCUSSION

Summative evaluation

Sixty-three growers voluntarily joined the project at its inception. However, the summative evaluation analysis showed results of only 57 participating growers, as six of the original growers withdrew from the project for various reasons.

Table 2. Status of participating growers before project implementation.

<table>
<thead>
<tr>
<th>Pre-project status question</th>
<th>Positive response (%)</th>
<th>Negative response (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the project, was there an irrigation scheduling method used in your farm?</td>
<td>16</td>
<td>84</td>
</tr>
<tr>
<td>Before the project, were there any irrigation records kept?</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>Before the project, was there a rain gauge?</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>Were rainfall data recorded and kept?</td>
<td>37</td>
<td>63</td>
</tr>
<tr>
<td>If Yes, are there available records?</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>Before the project, did you know your TAM?</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>Before the project, did you know your irrigation system application?</td>
<td>32</td>
<td>68</td>
</tr>
<tr>
<td>Before the project, did you have an auger?</td>
<td>7</td>
<td>93</td>
</tr>
</tbody>
</table>

Table 2 summarizes the status of the participating growers prior to the project. 84% of the participating growers did not practice any form of irrigation scheduling. Implementing any form of irrigation scheduling was difficult for them as the total
available moisture (TAM) of their soils (75%) and the application rates of their irrigation systems (68%) were unknown. Apart from irrigation scheduling, 77% of the participating growers did not keep any records on-farm. Keeping of records is not only essential in practising irrigation scheduling but in farming as a whole.

As 93% of the participating growers did not have the recommended soil augers, all participating growers were issued with Dutch soil augers for soil sampling to check soil moisture.

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, with 10.5% using Canesched and 5.3% using the Profit and loss book. Figure 2 also shows the other methods that the other 84.2% of 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 that continuous irrigation frequently results in significant over-irrigation, particularly early and late in the season (Heermann et al. 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 a potential to lead to either under irrigation or over irrigation. Only 1.8% would start their irrigation if the nearby estate that practice irrigation scheduling had started irrigating.

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

Formative evaluation

The formative evaluation was conducted and analysed for the four successive harvesting seasons of the project.

Improvement in record keeping

At the start of the project, the most prevalent records kept by the participating growers were harvesting records. Some 21% of the participating growers did not keep any record for their farms at the inception of the project. The impact of the project resulted in almost all of the participating growers keeping some form of record. The improvement was substantial from an average of about 8% in 2012/13 season to an average of 98% in the 2015/16 season. The improvement in record keeping by the growers will assist in achieving the first objective, as record keeping is essential for growers to increase their understanding of irrigation scheduling.
Reception of information

To meet the first objective, smallholder growers had to be provided with relevant information regarding irrigation scheduling techniques for sugarcane. Thus, actual daily ET values were sent to the participating growers. Feedback from the SMS programme showed that all the participating growers received information sent from the project office.

Irrigation scheduling techniques usage

At the inception of the project, the participating growers preferred the Pin-peg board method (Fig. 3). This is because it is a simple and user-friendly irrigation scheduling technique. However due to the ongoing training sessions, growers began to gain confidence in using the Profit and loss book. In the 2015/16 season, the Profit and loss book became the preferred method. Canesched was the least used method (<30%) because the use of this software depended on availability of a compatible computer on-farm and required a higher level of computer skills. These factors limited the adoption of this irrigation scheduling technique. Ronald et al. (1981) suggest that for a computerized irrigation scheduling system to be successful, it must be integrated into the total farming operation.

Impact of collaborators

To achieve the second objective, the smallholder growers were provided with training programmes that covered basic irrigation scheduling techniques. All the participating growers and/or their employees attended the training workshops.

Marvin and James (1981) state that irrigation scheduling activities are initiated with innovators to identify specific savings and yield benefits, and their testimonials are then used to influence early adopters. The project was implemented with 57 growers who volunteered to join the project and were used to influence other growers to adopt the irrigation scheduling techniques. The second group of collaborators were the extension officers. Marvin and James (1981) state that successful adoption requires that promoters understand social issues as technology transfer is affected by human behaviour. Owing to the wide scope of issues that extension officers had to deal with sugarcane growers, they required skills to deal with the social issues which could hinder adoption of the irrigation scheduling techniques. The project was further rolled-out to 79 further smallholder growers through their efforts.
Water and electricity savings

As irrigation water is often limited and expensive (Jones et al. 1990), and irrigation scheduling may be used to minimize electrical supply costs (Heermann et al. 1990), the participating growers were encouraged to keep water and electricity usage records. Six of the growers did not use electricity as their fields were under gravity-fed furrow irrigation. Table 3 shows the water and electricity savings made since the inception of the project. The participating growers who implemented the scheduling techniques showed water savings up to 22% in the 2015/16 season; and electricity savings up to 31% in the 2014/15 season. On average, about 7% of water and 10% of electricity were saved by the participating growers during the implementation of the project.

Table 3. Savings made in water and electricity used.

<table>
<thead>
<tr>
<th>Season</th>
<th>Water savings (%)</th>
<th>Electricity savings (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Average</td>
</tr>
<tr>
<td>2012/13</td>
<td>3.2</td>
<td>5.3</td>
</tr>
<tr>
<td>2013/14</td>
<td>1.1</td>
<td>5.4</td>
</tr>
<tr>
<td>2014/15</td>
<td>0.5</td>
<td>7.0</td>
</tr>
<tr>
<td>2015/16</td>
<td>2.1</td>
<td>8.2</td>
</tr>
<tr>
<td>Average</td>
<td>1.7</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Cane yield

One of the main objectives of the project was to improve yield and quality of sugarcane for smallholder growers. The yields and quality results were not measured but obtained from the SSIDB. Although proper statistical analyses were not applied because of the parameters that were not measured and controlled, the outcome from project fields and the other fields of the participating growers showed a similar trend over the period of the project implementation. The yields trend showed that the project fields performed better in cane yield (TCH) than the average of the other fields on the participating grower’s farm. On average, the project fields produced 2% more cane than the other fields over the four consecutive seasons (Fig. 4). The decrease in yields from 2014/15 to 2015/16 was reflected across the whole sugar industry due to unfavourable climatic conditions.

![Fig. 4. Cane yields from project fields compared with other fields of the farm.](image-url)
Cane quality

The amount of sucrose in sugarcane is considered an appropriate indicator of quality. Sucrose contents from the project fields were compared with the content from the other fields of the participating grower using results from the SSIDB. The results showed that, on average, the sugar yield (TSH) was about 4% higher in the project fields than in the other fields (Fig. 5).

![Smallholder Growers' Yields (TSH)](image_url)

**Fig. 5.** Sugar yields from project fields compared with other fields of the farm.

CONCLUSIONS

Overall, the project was a success because the following were achieved:

- 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.
- At the end of the project, growers who initially did not keep any form of irrigation and rainfall records were keeping them as well as other farming activities records.
- All the growers attended all the planned training sessions.
- On average there was 7% water and 10% electricity savings in the four consecutive seasons of implementing the irrigation scheduling project.
- Observed trends of the cane and sugar yields from the SSIDB showed consistently that the project fields were higher than the average yields of other fields of the farm by 2% and 4%, respectively.
- The project was extended to 79 new growers through the assistance of the participating growers and extension officers.

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We thank the following for their contribution in the project and the paper: The European Union for their substantial financial contribution; Staff of SSA, including the CEO, Head of department and other employees; Extension officers from the Swaziland sugar industry; All the smallholder growers who participated in the project; Dr M.V. Dlamini for initiating the project.
**RESUMEN.** La producción canífera de los pequeños productores es esencial en Swazilandia para combatir la pobreza y para el desarrollo económico rural. La superficie bajo cana en Swazilandia es de aproximadamente 59 000 ha, con menos del 4% en la superficie total de 14 000 ha bajo el control de los pequeños productores. Los servicios técnicos de la Asociación de Azucareros y de Servicios Técnicos de Swazilandia fueron voluntarios para participar. El método de programación de riego "Tarjeta del Pin" fue utilizado en el proyecto y permitió reducir las pérdidas en agua de hasta 21% y 30% respectivamente, y también redujo el costo de la electricidad. El proyecto ha sido un éxito, con un aumento del 8% en los rendimientos de caña de azúcar en Swazilandia.

**MOTS-CLÉS :** Pilotage de l’irrigation, petits propriétaires, fermiers, projet, canne.

**AUMENTO DE LOS RENDIMIENTOS DE CAÑA DE AZÚCAR Y DISMINUCIÓN DEL USO DE INSUMOS PARA PEQUEÑOS PRODUCTORES A TRAVÉS DE MEJORAS EN LA PROGRAMACIÓN DEL RIEGO EN SWAZILANDIA**

**Resumen.** El crecimiento de los pequeños productores de caña de azúcar en Swazilandia es esencial para aliviar la pobreza y el desarrollo económico rural. El área con caña de azúcar en Swazilandia es de aproximadamente 50 000 ha, con cerca de 14 000 hectáreas manejada por un gran número de productores de pequeña escala. La Asociación de Azucareros y de Servicios Técnicos de Swazilandia realizó un estudio en 1998 que mostró que los pequeños productores no siguieron ninguno tipo de programación de riego. La programación del riego es esencial para satisfacer las necesidades de agua de los cultivos y puede ayudar a reducir el costo del uso de la electricidad. Esta observación dio lugar a la iniciación de un proyecto de investigación de la programación del riego en la temporada 2011/12, financiado por la Unión Europea. En sus inicios, 63 productores de tres áreas de caña de azúcar en Swazilandia fueron voluntarios para participar. El método de programación de riego "Tarjeta del Pin-peeg" se utilizó en el proyecto debido a que los pequeños productores podrían entenderlo fácilmente. El método Tarjeta del Pin-peeg requirió a los cultivadores mover a diario un alfiler en una tabla, en función de la evapotranspiración del día (ET). Este método fue combinado con el 'libro de pérdidas y ganancias', con el software de programación de riego "Canesched" y la tecnología del sistema de mensajes cortos de teléfono celular para transmitir datos diarios de ET para los

**REFERENCES**


producto y para recibir retroalimentación de ellos. Además, los productores recibieron capacitación para mejorar su comprensión en la ejecución del proyecto. En general, el proyecto fue un éxito en los 4 años de ejecución a pesar de algunas dificultades. Más del 80% de los pequeños productores que participan en el proyecto implementaron los métodos de programación de riego. Los productores tuvieron beneficios de hasta el 21% y 30% en ahorro de agua y electricidad, respectivamente, además de la mejora en el mantenimiento de registros. Las tendencias observadas indicaron una mejora de aproximadamente el 2% en los rendimientos y 4% en calidad de la caña. En general, el proyecto fue un éxito ya que hubo ahorros en agua y electricidad y aumento en los rendimientos. El proyecto ha sido posteriormente implementado a 79 pequeños productores más.

**Palabras clave:** Programación del riego, pequeños agricultores, cultivadores, proyecto, caña de azúcar