REAL TIME IRRIGATION ADVICE FOR SMALL-SCALE SUGARCANE PRODUCTION USING A CROP MODEL

Report to the
Water Research Commission

by

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EXECUTIVE SUMMARY

Introduction

Water use efficiency in irrigated sugarcane agriculture is notoriously low and could increase dramatically if farmers implement established scheduling methods. A recent survey showed that 70% of sugarcane farmers use dragline irrigation and that 50% of these use fixed irrigation schedules. This leads to severe over-irrigation in times of low water demand and impacts negatively on the profitability of irrigated sugarcane production and on environment. Pressure is also building for water users to demonstrate efficient use of this scarce and sought after resource.

Numerous methods and tools are available to assist the farmer in scheduling irrigation, but adoption by the S.A. sugar industry has been disappointing. The rapid progression of communications technology (cellular communication and Internet) enables quick transfer of large amounts of data and information, further bolstering the potential usefulness of computerised irrigation decision support systems (IDSS). A survey amongst S.A. sugarcane farmers and extension officers showed that IDSS were too complex and impractical to be useful to farmers. In practice, farmers tend to use instinct or simple tools that they understand, even though these may be less accurate and inefficient.

The challenge therefore is to provide simple, practical and useful advice to farmers using state of the art technology such as crop models and weather stations, and to convince farmers of the benefits of irrigation scheduling through on-farm demonstration.

The project objectives were to:

- Develop and refine an automatic irrigation advice system consisting of automatic weather stations, a web-based crop model and a cellular communication network.
- Implement the system for small-scale farmers in Pongola and the Makhathini flats.
- Evaluate the suitability of the system for providing useful irrigation advice and to determine likely adoption rates and impacts on water use.

System development

The ***MyCanesim*** system was successfully improved by developing and implementing a user-friendly, web-based graphical user interface that allows users to set up simulation runs, manipulate simulation input data and view various system reports (including irrigation advice). Extension staff and other role-players were involved in the design and testing of the interface.

A control module was created to allow for the smooth operation and monitoring of the ***MyCanesim*** system. It allows the system administrator to activate or deactivate schemes and fields listed for batch running, to edit key field input variables such as cell numbers and harvest dates, to edit historic irrigation schedules and to manage advice dissemination.

A facility was also developed that enabled farmers to send a blank SMS reply to the ***MyCanesim*** system when they chose not to, or could not, follow advice. The reply is automatically interpreted in the context of the specific advice and then used to adjust assumed irrigation records used as simulation input. The facility works correctly but has seldom been used by farmers, in spite of numerous requests to do so.

Although the ***MyCanesim*** system eventually executed successfully more than 95% of the time, there is room for code optimisation to reduce runtime. There is also a need for more powerful processing power to speed up execution speed to accommodate all prospective users.

System implementation: Pongola

The system was implemented fully on the Pongola small-scale irrigation scheme. Subscription to the service grew steadily from 5 in 2005 to 41 in 2008. Several challenges were met during implementation. Amongst these were:

- Difficulty in obtaining good quality irrigation and rainfall data timeously from farmers. This affected the accuracy of simulations and the relevance of advice.
- Conflict sometimes being created by generating independent (and sometimes contrasting) advice to farmers who shared pumps. This problem can be overcome by making code changes that will synchronise advice as far as possible.
- Unreliable fax and inadequate Internet access was a problem for extension staff at both schemes.

It also became clear during implementation that regular and meaningful interaction between project technicians or extension staff and farmers are crucially important to maintain enthusiasm and assist with interpretation and practical implementation of advice.

The project helped extension staff and farmers gain a much better understanding of the important factors that determined the crop water balance and how irrigation can be scheduled to impact positively on productivity and sustainability.

The various reports available from the system provide concrete information (albeit simulated) for extension staff to benchmark irrigation practices, growth and yield of individual fields. The simulated results provided a good basis for discussion with farmers during field visits to identify agronomic practices that limited yields, such as poor crop stand, insufficient weed control, erratic movements of sprinklers and excessive sprinkler stand times leading to alternating periods of water logging and drought.

A demonstration field day held in Pongola on 5 September 2007 was attended by 130 small-scale farmers and other interested persons from Mpumalanga, Makhathini flats and Pongola. Project team members explained the objectives of the project and how the ***MyCanesim*** system works. Three fields were visited and farmers explained how they participated in the project and benefited from the advice. This event stimulated the curiosity of farmers from other areas and exposed them to the potential of irrigation scheduling to improve yields, cut costs and improve the profitability of their businesses.

Observations of canopy cover, soil water status and cane yield in four fields in 2005/06, and in nine fields in 2006/07, show that model simulations of these variables were reasonably accurate when the Canesim model was supplied with accurate input data. Simulated canopy cover and yield compared well with observed values. Wetting front detector responses suggest that the Canesim model sometimes underestimated soil water status and it is recommended that this problem be further investigated with a view to improve the model.

The study showed that, for Pongola, the spatial variation in rainfall was low and that rainfall data recorded by a single automatic weather station was sufficient for accurate simulations. The study also showed the importance of accurate irrigation data input. It proved quite difficult to obtain timeous and reliable irrigation data from farmers. Assumptions that farmers followed advice to irrigate or not were not always correct and this led to incorrect simulations and advice about 5% of the time. The main reason for farmers not following advice was lack of water supply when advised to irrigate. The causes of this were electricity cuts due to non-payment, pump breakdowns and interruptions in water supply at scheme level.

Factors outside the scope of this study unfortunately played a dominant role in the long-term trends in water use and cane yield observed on the Pongola scheme. Declining water availability, changed method of payment for water and lack of infrastructure maintenance contributed to a general decline in irrigation water use and yield. However subscribers to the service experienced slower rates of decline and applied more water and achieved higher yields than non-subscribers. This suggests that the advisory service had a beneficial impact on the productivity and profitability of farmers who subscribed to the service.

System implementation: Makhathini

Implementation at Makhathini was problematic. Five fields were monitored in 2005/06 and advice was provided to an equal number of farmers. However, only two farmers out of twenty-three that were evaluated fulfilled the criteria for monitor participants, and in 2006/07 only two fields were monitored. The main problem was inadequate irrigation systems that result in excessively long irrigation cycles that exceed the design specifications by two or threefold. In practice, this amounts to supplementary irrigation. Irrigation was often also stopped entirely midway through the growing season because sprinkler stands were too short to distribute water above the cane canopy.

Another frustration was the unavailability of quality data at field and scheme level. It was very difficult to obtain reliable irrigation and rainfall data during the first season because it was difficult to make farmers understand the trial objectives and methods. The integrity of yield data at a scheme level is questionable, while no water use data was available. It was further impossible to obtain harvest schedules in advance. This makes effective research and service provision impossible. It was therefore decided to terminate field monitoring in May 2007, while advice is still provided to all farmers that subscribed.

Most Makhathini farmers were unable to benefit from the advice because the irrigation systems are inadequate to supply the required amount of water. It is estimated that, on average, farmers could and should have applied approximately 85% more water, even with the long irrigation cycles of existing systems. This caused an estimated yield shortfall of 60%. The estimated irrigation and yield shortfalls are much larger when benchmarked against ideal irrigation schedules with the specification cycle of 7 days. Despite numerous attempts to convince participants to upgrade and repair irrigation systems and to improve crop husbandry, nothing has changed. Lack of land ownership, lack of cash flow and a 12-hour per day water supply are severe limitations to correcting these problems.

Farmer survey

Interviews with 20 Pongola farmers showed that most farmers found the irrigation advice useful and easy to understand, and trusted the advice most of time. The project made farmers more aware of the importance of irrigation scheduling in increasing revenue and reducing costs, and most farmers have changed irrigation practices because of the advice. The majority of farmers indicated that they wanted the service to continue and were prepared to pay a small service fee.

Economic feasibility study

The study suggests that farmers can obtain a positive net benefit from the "Advice only" service. The benefit of the more costly "Advice plus monitoring" is more doubtful. These results are based on the assumption that the service will result in a saving of 584 mm of irrigation water per season. Model recalculations with more realistic impacts show that a full cost recovery for the "Advice only" service (R649 to R384/ha depending on subscription levels) would only be feasible in scenarios where cane yield can be increased (by as little as 4 t/ha) by better scheduling. It is unlikely that service implementation costs can be fully recovered from irrigation water savings only.

General

The approach used here for developing and implementing an irrigation decision support system proved highly appropriate. The fact that users were involved in the design and implementation and the fact that system complexity was hidden from users contributed to quick and wide adoption of the technology. It was also shown that there is no need to scale down on technology when providing decision support for small-scale farmers. In fact, modern technologies such as the Internet, cellular communication, electronic weather stations and crop models made it possible to (1) develop a system that addressed the unique needs of small-scale farmers and their agents and (2) overcome many constraints.

It is believed that this type of irrigation scheduling advisory service (as provided to Pongola small-scale farmers) has many indirect benefits (e.g. reduced soil degradation, reduced leaching of nutrients) that were not monitored in this project. The study showed that significant direct (monetary) benefits are possible, provided the following prerequisites are in place:

- Reliable and adequate supply of water,

- Adequate irrigation systems,
- Adequate control over water supply and irrigation at the field level,
- A sense of ownership of land and infrastructure,
- Monetary incentives for farmers to benefit from water savings,
- Willingness of farmers or water use agencies to contribute to the cost of service delivery,
- Competent and committed support from field support agents that are needed to assist farmers with implementing advice and to obtain accurate field data,
- Adequate Internet access and fax facilities for field support agents, and
- Adequate computer processing power and optimal system code to reduce system run time and enable system expansion.

The project provided ample opportunity for capacity building. The 47 farmers from Pongola and Makhathini that were directly involved in the project enhanced their knowledge and skills needed for irrigated sugarcane farming. KZN DAEA and Illovo mill extension staff learnt how to use crop and weather data to assist them in their job. Project researchers learnt more about participative research, while the two project technicians learnt how to interact with farmers and capture and process field data. Both technicians have also furthered their studies, one towards a diploma and the other towards a degree in agriculture.

Recommendations

An advisory service that provides real time irrigation scheduling advice based on weather data could be implemented on other sugarcane irrigation schemes, provided that the stated concerns are addressed. It is recommended that:

- The issues of landownership, inadequate irrigation infrastructure and inadequate or inflexible water supply are resolved first before considering the implementation of an irrigation scheduling advice service.
- Modern broadband technology is implemented to address the inadequate Internet bandwidth at support agencies in rural areas.
- Fax machines of the KwaZulu-Natal Dept. of Agriculture Office in Pongola are fixed and properly maintained.
- Staff from government agencies (such as Water Users' Associations, Dept. of Water Affairs and Dept. of Agriculture) and sugar industry organisations (such as SASRI and Milling companies) are trained to understand and use the ***MyCanesim*** system. Apart from providing real time scheduling advice, it could also provide information to predict water use and yields and compare these to actual yields and water use.

- The use of electronic equipment to monitor irrigation and rainfall at a field level and integration of this data into the ***MyCanesim*** system are explored to improve the quality of simulation output and advice.
- Aspects of the system are customised to address the unique needs of each irrigation scheme or scenario. This requires involvement by potential users (farmers and their support agents) and a phased implementation.
- Full cost recovery of such a service is unlikely under the current scenario. Subsidisation by role-players who have an interest in more efficient use of irrigation water must be considered, or alternatively a scheme should be devised to provide a better incentive for farmers to subscribe to such a service.

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All these contributions were crucial in achieving success in the project and are gratefully acknowledged by the authors.

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LIST OF ABBREVIATIONS

Abbreviation	Name	Units
AI	Number of advised irrigations	
AS	Adherence score	%
ASW	Available soil water content	mm/m
ASWC	Available soil water capacity	mm/m
AWS	Automatic weather station	
BCR	Benefit to cost ratio	
CC	Canopy cover	%
CY	Cane yield	t/ha
DSS	Decision support system	
IA	Index of agreement	%
IDSS	Irrigation decision support system	
IWU	Irrigation water use	mm
IWUE	Irrigation water use efficiency	kg/m^3
IWU_{Flow}	Irrigation water use measured by flow meter	mm
IWU_{Gauge}	Irrigation water use measured by field rain gauge	mm
RAM	Random access memory	
RMSE	Root mean square error	
SMS	Short message service	
UI	Number of unadvised irrigations	
US	Number of unadvised stops	
WFD	Wetting front detector	
WFD50	Wetting front depth of at least 50 cm	

1. INTRODUCTION

1.1. Background

Water use efficiency in irrigated sugarcane agriculture is notoriously low and could increase dramatically if farmers implement established scheduling methods. A recent survey showed that 70% of sugarcane farmers use dragline irrigation and that 50% of these use fixed irrigation schedules (Olivier and Singels, 2004). This leads to severe over-irrigation in times of low water demand and impacts negatively on the profitability of irrigated sugarcane production and on environment. Pressure is also building for water users to demonstrate efficient use of this scarce and sought after resource.

Irrigation scheduling could be defined as a planned programme of irrigation application specified by dates and amounts to achieve given objectives. Typically these objectives could be to maximise profits, maximise water use efficiency, avoid water wastage, avoid plant stress or achieve maximum yields (Lamacq et.al., 1996). Operationally these objectives are often achieved by attempting to maintain soil water content within a target range given the constraints of the soil and irrigation system.

Numerous methods and tools are available to assist the farmer in achieving these objectives. These could be grouped into methods based on water budget calculations or methods based on direct measurement of soil water status. The first group is based on some measure of atmospheric evaporative demand and a crop coefficient that describes the amount of canopy cover and soil surface wetness (Jensen *et al.*, 1990). Either real time or long-term average values could be used for both these variables. Real time values are normally used in conjunction with sophisticated water budget calculators such as crop models and require access to daily weather data (Teixeira *et al.*, 1995; McGlinchey and Inman-Bamber, 1996; Singels *et al.*, 1998), while long-term averages are used in simpler methods such as spreadsheets and do not require access to daily weather data apart from rainfall (George, 1988). Generally, the water budgeting method using models has not been adopted widely (Stephens and Middleton, 2002; Leib *et al.*, 2002).

The rapid progression of communications technology (cellular communication and Internet) enables quick transfer of large amounts of data and information, further bolstering the potential usefulness of agricultural (and irrigation) decision support systems (DSS). However, the general experience is that the adoption of DSS has been very disappointing due to various reasons, e.g. lack of end-user input into the development of DSS, no clear advantages of using DSS and lack of training (Stephens and Middleton, 2002). Oliver and Singels (2004) found that irrigation scheduling DSS were too complex and impractical to be useful to South African sugarcane farmers. In practice, farmers tend to use instinct or simple tools that they understand, even though these may be less accurate and inefficient.

The challenge therefore is to provide simple, practical and useful advice to farmers using state of the art technology such as crop models and weather stations, and to convince farmers of the benefits of irrigation scheduling through on-farm demonstration.

SASRI has developed a prototype of a system (called ***MyCanesim***, see Singels and Smith, 2006) consisting of the following: ·

- weather data recorded by automatic weather stations and remotely downloaded daily through the cellular network, ·
- a web-based simulation model that estimates the recent, current and future water balance, crop status and yield on various positions in a field from weather, irrigation and field data, and suggests irrigation actions, ·
- an Internet-based user interface for advisors and extension staff to enter field, crop and irrigation system data and to view simulation results,
- the automatic distribution of irrigation on/off advice in isiZulu through SMS technology to farmers' cellular phones.

In a pilot case study, the system has been implemented in 2004 on a limited scale in Pongola (Singels and Smith, 2006). Irrigation advice was provided to five small-scale farmers and its impact monitored. Initial results were very promising and indicated that water savings of up to 25% and cost reduction of R1200/ha could be achieved for small-scale farmers.

These results suggest that a wider implementation of this service could be explored. These direct benefits are potentially possible to more than 1500 small-scale farmers in Pongola, the Makhathini flats, and the Komati area on approximately 8000 ha. The technology could also be used by commercial farmers on 56 000 ha. Indirect environmental benefits are reduced water extraction from river systems, and reduced runoff, deep drainage and water pollution.

1.2. Objectives

The project objectives were to:

- develop and refine an automatic irrigation advice system consisting of automatic weather stations, a web based crop model and the cellular communication network.
- implement the system for small-scale farmers in Pongola and the Makhathini flats.
- evaluate the suitability of the system for providing useful irrigation advice and to determine likely adoption rates and impacts on water use.

2. SYSTEM DEVELOPMENT

2.1. Overview

The various components of the system and a chronology of daily data flow and the management thereof is depicted in Fig. 2.1. The functionality of the system is illustrated in Fig. 2.2 by showing the interaction between various software components, data tables and telecommunications. A detailed description of all procedures and data tables is given in the Appendix 11.1.

The ***MyCanesim*** system uses capabilities offered by modern technology namely the Internet, cellular communication, electronic monitoring of resources, mathematical modelling and computers. It is described by Singels and Smith (2006). Briefly, it consists of:

- A database of model inputs and outputs.
- A sugarcane simulation model that estimates the recent, current and future water balance, crop status and yield for a number of positions in a field. The Canesim model is a daily time step, point-based simulation model driven by water, temperature and radiation. It requires soil available water holding capacity and daily temperature, rainfall and reference evaporative demand as input. The model accounts for partial canopy conditions and soil water content using a single layer soil profile. Sucrose and cane yield is calculated by combining a radiation use efficiency approach with source-sink principles (Singels and Bezuidenhout, 2002). The water balance of Canesim is described by Singels et al. (1998) and the canopy development by Singels and Donaldson (2000). These publications also report on the validation of various aspects of the model against observed data, indicating the soundness and accuracy of the model for the purpose of this study.
- An irrigation scheduling and advice module that, when activated by the user, (1) determines the ideal irrigation schedule based on the water balance of various positions in each field, and (2) automatically generates and disseminates irrigation advice and yield estimates.
- An Internet-based user interface for farmers, extension staff and mill management to enter or edit field, crop and irrigation system data and to view or download irrigation advice, yield estimates and field reports. The interface has a user-friendly layout with an expandable/collapsible menu tree that, when activated, populates a neighbouring frame with the relevant template or information. An initial prototype of the interface was discussed with eight prospective users during a workshop and subsequently refined according to their comments.

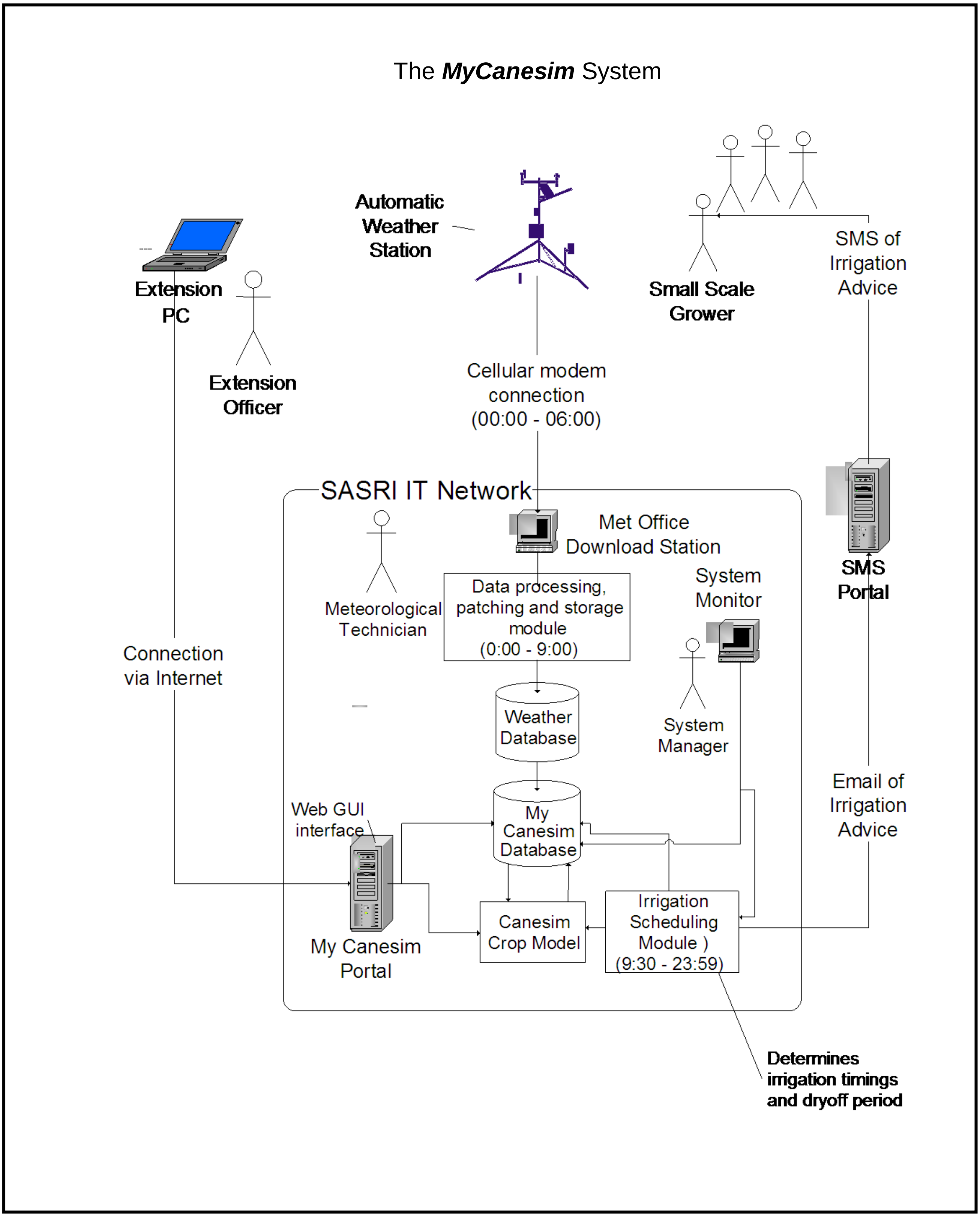


Figure 2.1 The various components of the *MyCanesim* system showing the flow and management of information (from Singels and Smith, 2004).

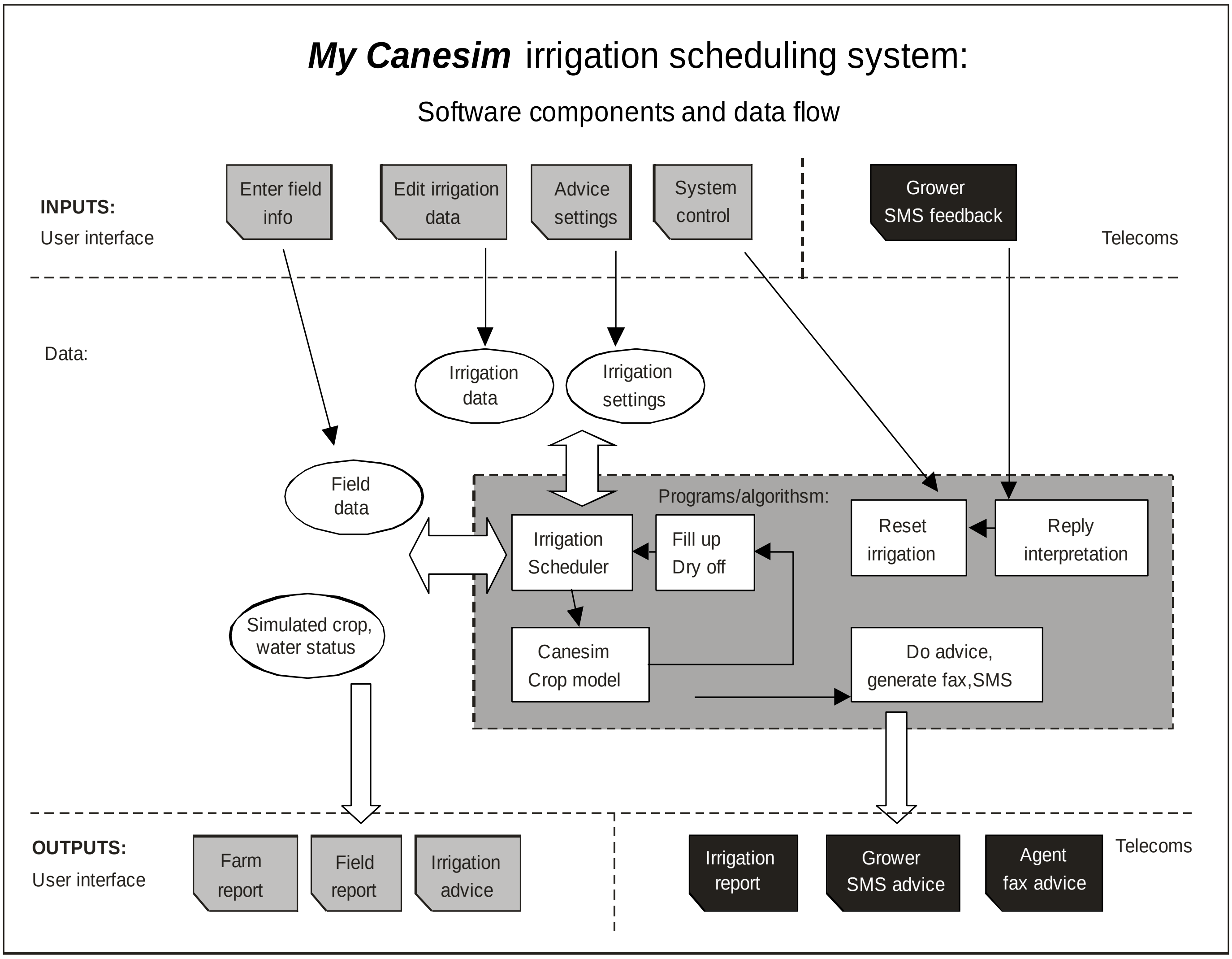


Figure 2.2 The interaction of software and data components of the *MyCanesim* scheduling system. More detailed information on each component is given in Appendix 12.1.

The following input data are required by the system:

- Daily weather data downloaded from 24 automatic weather stations situated throughout the South African sugar industry (see Singels et al., 1999).
- Plant available water capacity and plant available water of the root zone at the start of the crop.
- Cultivar, row spacing, plant or ratoon date and planned harvest date.
- Irrigation system, irrigation cycle, net irrigation amount per application.

The system outputs daily values of cane yield and quality, crop and soil water status, canopy cover, cumulative water balance totals and irrigation advice. These data are used, via the interface, to produce reports that summarise data in numerical and graphical format at the irrigation scheme or field level. Output can be printed as hard copy or exported into Microsoft

Excel for further analysis. Output data are also disseminated to farmers via short message service (SMS) text messages on the cellular network whenever an action is required (for example ‘stop irrigating’), and to extension and mill staff via facsimile on a weekly basis. Output options are summarised in Table 2.1.

The format and content of the various reports and recommendations were designed in accordance with users' preferences obtained during several workshops (see section 3.4.3) with all stakeholders concerned.

The SMS irrigation advice to farmers comprises a suggestion to resume or stop irrigation of their field, with an estimate of current and final cane yield. The fax summary of irrigation advice contains information for each field in a given scheme, on the current irrigation action (irrigating or not), the expected date of the next action (stop or resume), the expected date of the last irrigation, current cane yield and rainfall and irrigation totals to date.

The system was demonstrated to a group of SASRI extension staff and researchers at a DSS workshop in October 2006. A survey conducted afterwards (Pers. comm., Van den Berg, SASRI), showed a very favourable response to questions about the system's user-friendliness. The average response to its usefulness as a support tool for research and extension was neutral with a wide range of opinions. It was regarded as very useful for staff dealing with irrigation scheduling. A need for training in the use of the system was expressed.

Table 2.1 *MyCanesim* output.

Type	Content	Level	Primary user	Delivery method
Irrigation advice	Current and future yield, irrigation recommendation for a given field.	Field	Farmer	SMS
Farm report	A summary of all fields on a farm/scheme in terms of the current water balance, and cane yield and quality at harvest.	Scheme		Web
Field report	Comprehensive data containing values for each day of the season of the various water balance components, cane yield and quality.	Field		Web
Irrigation report	The date and amount of each irrigation event for the specified block, seasonal statistics.	Field		Web
Rainfall report	The date and amount of each rainfall event for the specified gauge, seasonal statistics.	Field		Web
Irrigation advice	Summary of current water balance and advice for all fields subscribed to irrigation advice service.	Farm, Scheme	Extension	Web, Fax
Yield estimates	Summary of input parameters and final water balance and yield estimates.	Farm, Scheme	Extension, mill staff	Web, Fax

A brief functional description of each of the software components that were developed in this project now follows.

2.2. The *MyCanesim* system user interface

An existing prototype of the web-based user interface was upgraded to enable easy and efficient editing, viewing and downloading of input and output data. The interface was developed in Oracle Portal (Oracle Corp.) and has a user-friendly layout with an expandable/collapsible menu tree that, when activated, populates a neighbouring frame with the relevant template or information. Two separate menu sets are used for two groups of users, namely (1) farmers or their agents and (2) scientists. The first group requires support for tactical decisions within a given crop season based on real time weather data, such as irrigation scheduling. The second group would primarily be interested in the evaluation of production strategies based on past weather data. The terminology between these groups differs. The menu structure, selected data entry templates and report screens for the tactical users are shown in Fig. 2.4 and 2.5.

The functions of the most important menu options are described in Table 2.2. Most data capture screens test user input against a valid data range before submission to the database.

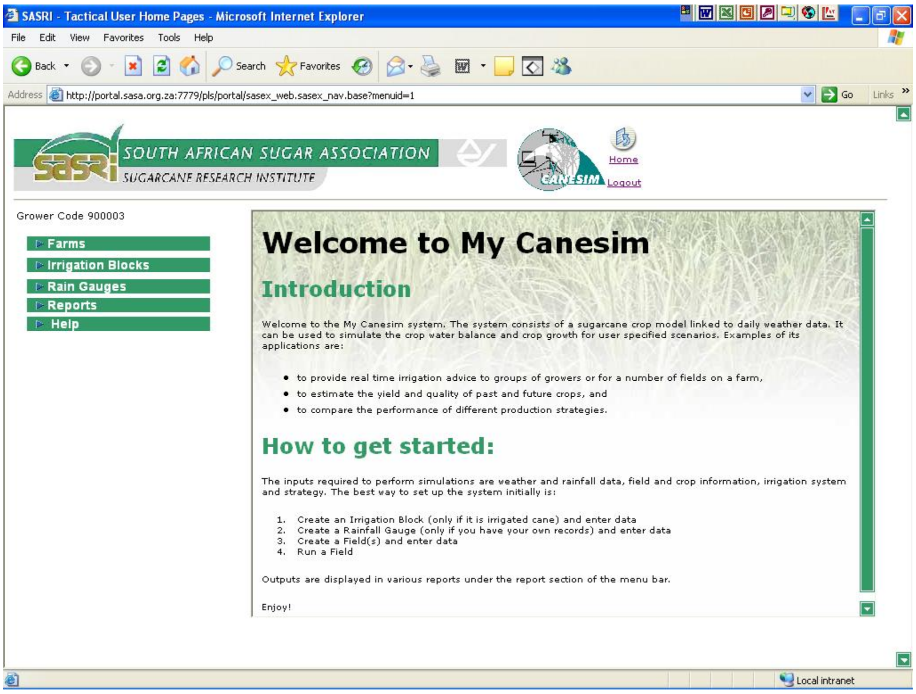
A successful workshop was held on 9 September 2005 with prospective users to test out the new prototype and to get suggestions for improvements (see Fig. 2.3). Most of these have been addressed fully. The final version of the user interface was fully installed on the ***MyCanesim*** portal server in 2006 and is publicly accessible at http://portal.sasa.org.za, although access is restricted (user name and password required).

Figure 2.3 Users test the prototype of the *MyCanesim* user interface during a workshop held at Mount Edgecombe.

Table 2.2 The primary and lower level (indented) menu options of the *MyCanesim* user interface.

Menu option	**Function**
Farms	Define farm properties.
Fields	Enter and edit field, soil, crop and irrigation system properties, define irrigation strategy.
Irrigation	Display historic irrigation data for specified field.
Rainfall	Display historic rainfall data for specified field.
Irrigation blocks	Define irrigation blocks.
Capture irrigation	Enter and edit irrigation data for specified block.
Rain gauges	Define rainfall gauges.
Capture irrigation	Enter and edit rainfall data for specified gauge.
Reports	
Farm report	Generate a summary of all fields on a farm in terms of the current water balance, and cane yield and quality at harvest.
Field report	Information on the current and final water balance, cane yield and quality.
Irrigation report	Report date and amount of each irrigation event for the specified block, seasonal statistics.
Rainfall report	Report date and amount of each rainfall event for the specified gauge, seasonal statistics.
Irrigation advice	Summarise current water balance and advice for all fields subscribed to irrigation advice service.

(a)



(b)

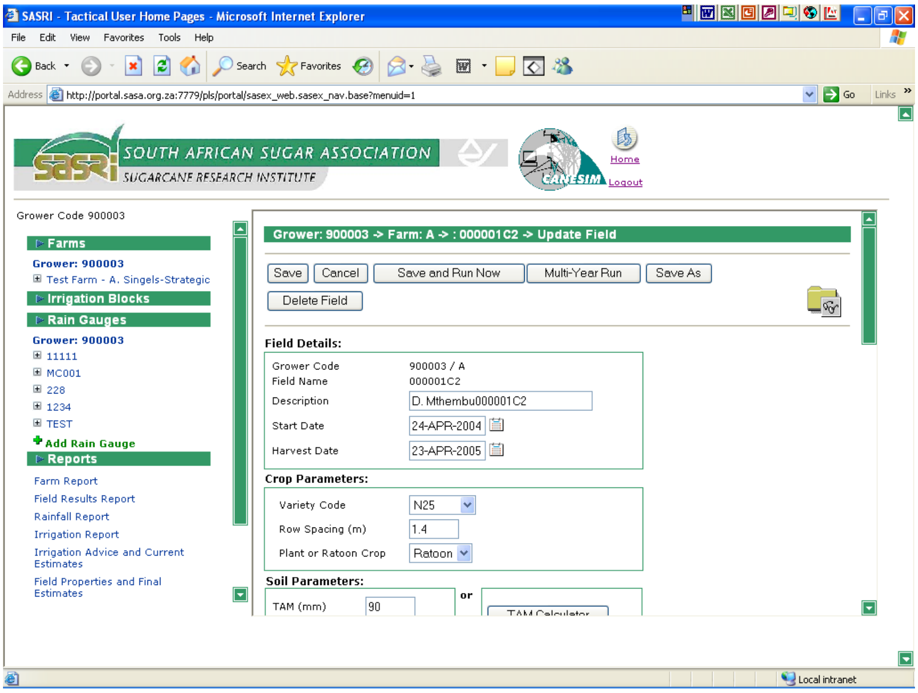


Figure 2.4 Examples of input and output screens of the *MyCanesim* user interface. The welcome screen (a) and examples of the field input template (b) are shown.

(c)

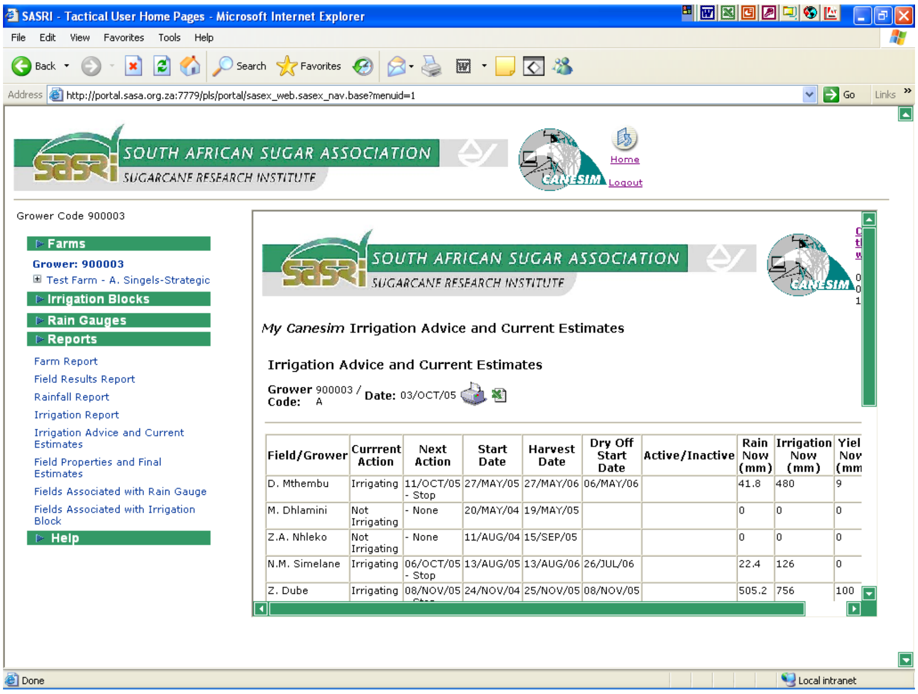


Figure 2.5 An example of the irrigation advice report generated by the *MyCanesim* user interface.

2.3. System control module

A system control module was developed to provide functionality for the system administrator to operate and monitor the ***MyCanesim*** system efficiently. It allows the manipulation of operational settings, editing of key field input data such as harvest dates and irrigation schedules, and the monitoring of advice generation and dissemination. Fig. 2.6 shows the main screen and illustrates the various functions available on the module.

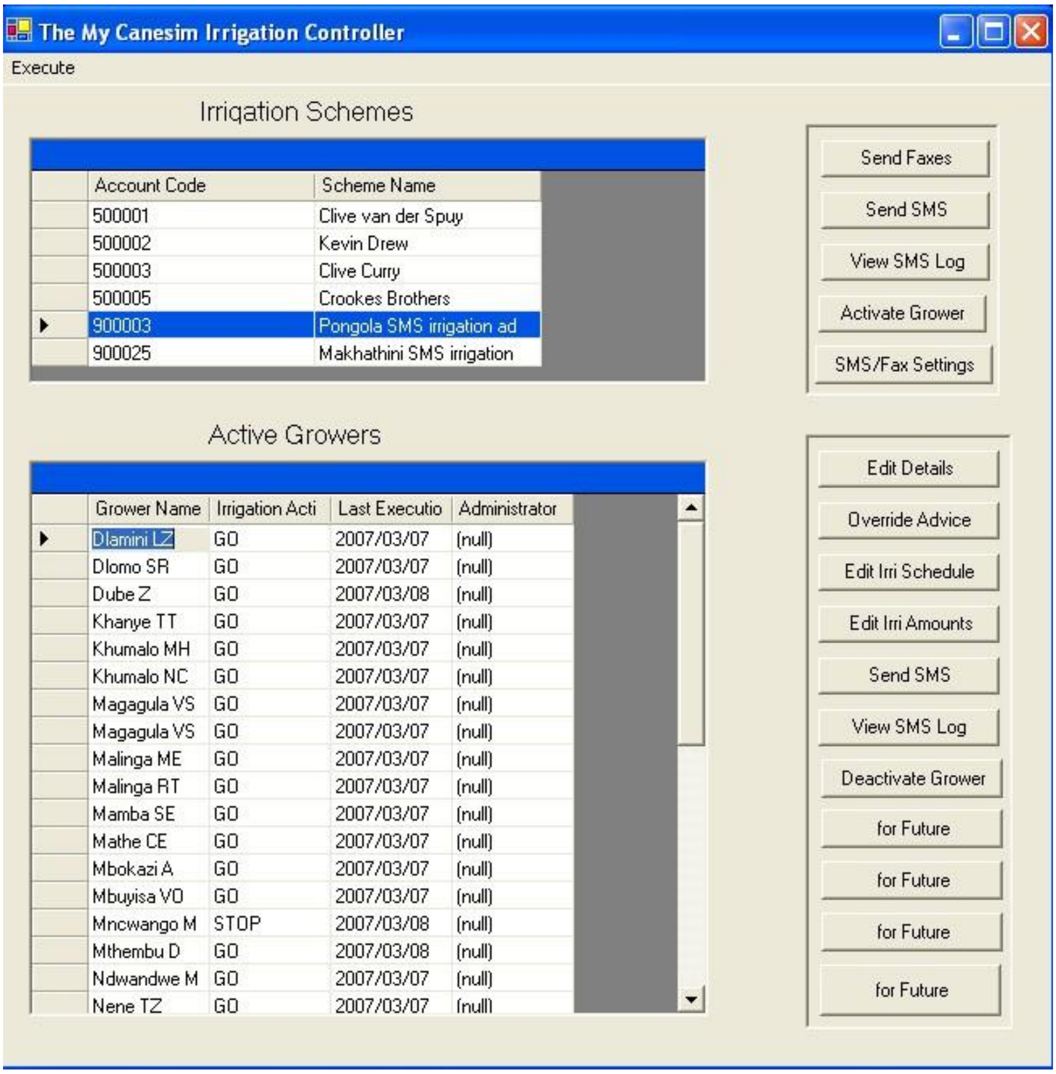


Figure 2.6 The main window of the system control module.

The main menu options are:

- Scheme/Farm level:
- Send Faxes: Send summary reports to all persons registered.
- Send SMS: Compile and send a custom SMS to all active farmers of the selected scheme.
- View SMS log: View details of all SMS advice.
- SMS/Fax settings: Set cell phone and fax numbers of persons registered to receive scheme summary reports for the selected scheme.
- Activate farmers: Displays a list of fields that could be selected for execution by the system.

Field level:

- Edit details: Change details for selected fields.

- Override advice: Override advice from system with predetermined advice for the selected field.
- Edit irri schedule: Add or remove irrigation events for the selected field.
- Edit irri amount: Change the amount of irrigation applied in a given cycle for the selected field.
- Send SMS: Send a custom SMS to the selected field/farmers.
- Deactivate farmer: Removes a field from the group of fields available for execution.

The module also has an “Execute” menu at the top of the window that allows the administrator to select fields for immediate manual execution.

This final version of the control module has been in use since December 2006 without any problems and provided the needed functionality for smooth system operation.

2.4. Reply path

The reply path feature is designed to allow farmers to decline the advice sent to them, when they cannot or choose not to comply with it. It consists of a blank SMS reply to the sender of the ***MyCanesim*** irrigation advice. The reply is then interpreted by the SMS irrigation advice program in the context of the advice provided, to adjust the irrigation records for that farmer accordingly. For example, if the advice was to irrigate and the farmer chose not to irrigate, the blank reply will cause the removal of an irrigation event on that day. This information will be used in the next simulation the following day.

The system was implemented and communicated to farmers during 2006. It was used by Mthembu on 29 July 2006, and by Simelane on 22 November 2006, to convey the unavailability of water. The correct processing of the replies was verified.

There were many instances where farmers did not use this function when it was required. Despite continued encouragement from the project team, farmers generally did not make use of this facility. It is concluded that this method of obtaining feedback from farmers about irrigation practices does not seem to be feasible and that further investigation is required to establish the reasons why and to design an alternative solution.

2.5. System performance

System performance was monitored throughout the project on most weekdays. ***MyCanesim*** failures (simulation batch not fully executed or advice not disseminated) were mostly due to power failures, network or server failures, software crashes due to incomplete input data, runs extending across the data change or coding errors. Some of these problems were overcome by (1) installing an Uninterrupted Power Supply to ensure a smooth transition from ESKOM to SASRI generated power, (2) optimising data downloading, processing and simulation schedules and (3) eliminating coding errors. During the last year system failures (defined as cases where fewer than 90% of simulation runs were completed successfully) were reduced to 4% of the time (or about every 25th day). This is regarded as acceptable.

The ***MyCanesim*** system currently operates on a personal computer with Pentium 4 (2.8 MHz) processor with 504 MB of RAM. The system currently executes daily runs for 60 fields (41 for the Pongola small-scale scheme, 5 for the Makhathini scheme and 14 commercial fields). The daily batch starts at 09:30, after verification that the weather downloads and processing was completed successfully. With the current configuration the batch takes approximately 12 hours to complete. Batch run time varies and depends on the how much future time needs to be considered by the system (min of 10 hours and max of 15 hours). The system needs to finish before 24:00 to allow weather data downloads and processing to start for the following day.

During an operational test it was determined that execution time can be reduced by 85% if:

- the Canesim crop model code was written in C# instead of in PL/SQL,
- weather data was stored in memory arrays for repeated use, instead of being read from the database each time,
- model output is stored in memory arrays for writing to the database at the completion of a run instead of after each daily time step.

There are further opportunities for code optimisation such as reducing the number of calls to the crop model from the scheduling algorithm and simplifying the scheduling rules. Assuming that execution time could be reduced to 1 min per field, it is possible to simulate 900 fields from 09:00 to 24:00. No runs are possible between midnight and 09:00 the following morning as new weather data are downloaded and processed (including 08:00 to 08:00 rainfall) and the system is checked. It is clear that more processing power is needed if the service are to be expanded, or if the system is used for other applications such as research projects.

3. SYSTEM IMPLEMENTATION

3.1. Introduction

The aim was to phase the implementation of the system over two crop growth cycles. In the first cycle the system was to be implemented and evaluated with a small group of farmers only. This would allow for intensive monitoring and farmer interaction and opportunities for refining the system. These participants are called monitor participants.

In the second phase the service was to be expanded to all willing farmers on each scheme (approximately 45 potential users at Pongola and 300 at Makhathini). Farmers that only receive advice are called advice participants. Intensive monitoring and evaluation continues with monitor participants, and in addition there is impact assessment on a scheme level as well.

The second phase would only commence after the results from the first phase suggest that it would be feasible. Phase 2 for Pongola commenced in April 2006, while phase 2 for Makhathini was due to start in April 2007, but was abandoned because of inadequate irrigation infrastructure, inadequate agronomic management and difficulties with obtaining good research data. This situation is elaborated in section 3.4.

3.2. Background of two small-scale irrigation schemes

The system was implemented on the Bivane small-scale sugarcane irrigation scheme in Pongola and on the Makhathini flats.

The scheme at Pongola consists of 47 farmers on 508 ha of land. Semi-permanent overhead systems are used on 44 farms. Each farmer farms 7-15 ha and typically has 20 sprayers moving amongst 20 to 28 positions. The stand time is 11.5 h (two moves per day) and the effective application rate is 3.6 mm per hour giving a net application of 42 mm. The irrigation cycle varies from 8 to 14 days. Fig. 3.1 shows a typical irrigation setup in a sugarcane field in Pongola.

Figure 3.1 Semi-permanent sprinklers operating in a field of young sugarcane in Pongola.

Cane yield in 2003/04 varied from 31 to 137 t/ha with a scheme average of 93 t/ha. The average amount of irrigation water used on the scheme in 2004 was 921 mm. Fifteen farmers exceeded the annual quota of 1000 mm in 2004. Payment for irrigation water and electricity to apply irrigation are illustrated in Fig. 3.2. In 2004/05 costs consisted of operational costs of the scheme (R508/ha), levies (R45.30/ha), booster pumping costs (R1029/ha), infield pumping costs (R0.889/mm on average) and a subsidy from Dept. of Water affairs and Forestry (-R589/ha). Total annual costs amounted to R1887/ha assuming a water use of 1000 mm. Costs increased with each season due to inflation and a reduction in the subsidy. Also, more importantly, from 2006/07 the booster pumping costs was calculated on a volumetric basis instead of an area basis, thereby providing an added incentive to save irrigation water.

The method of payment also changed during the course of the project. Initially (2004/05) the total costs for each farmer were calculated by the Impala Water Users' Association (pers. comm. Boonzaaier, Impala Water Users' Association) and this was then deducted from the mill payment for cane deliveries. Subsequently the responsibility for payment of electricity cost to operate infield pumps was transferred to farmers.

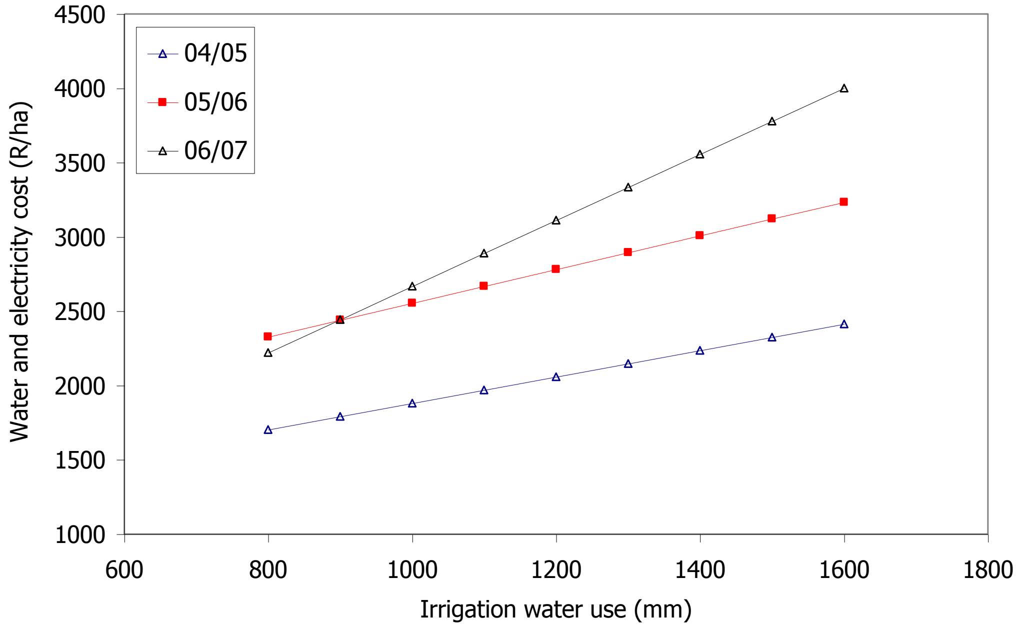


Figure 3.2 Total cost of irrigation water (including application cost) for Pongola small-scale farmers.

The area under sugarcane in Makhathini is approximately 3000 ha with 268 farmers. The average farm size is approximately 10 ha, which is leased from the state. The main method of irrigation is by semi-permanent or moveable overhead systems. Water is available between 05:30 and 19:00, 7 days a week. Main pumps are stopped when rainfall exceeds 40 mm. Sprinklers are moved once a day and the original design is for an irrigation cycle of 7-9 days and a net application of 35 to 55 mm. (pers. comm., S. Pienaar, EVN Africa).

There is no water quota in place (there is no Water User Association to our knowledge) and the farmers paid a flat rate of R137/ha/month (2005) to Mjindi Farming, a government agency responsible for water distribution. Many farmers have operational flow meters and it is envisaged that a volumetric costing structure for water will be phased in to replace the current flat rate.

3.3. Weather data

The ***MyCanesim*** system uses daily weather data to calculate water use and crop growth. This information is used to generate irrigation advice for subscribers to the service. For the advice to be relevant, the data is needed near real-time.

For the Pongola scheme, data from the SASRI automatic weather station (AWS, 27°24'S, 31°35'E, 308 m) established in 1996 and located about 1 km from the nearest small-scale field to about 5 km from the furthest field, is available. For the Makhathini flats, a new automatic weather station (CS Africa Ltd., Somerset-Wes) was erected at the Agricultural Research Station (27°24'S, 32°11'E, 69 m asl) on the 18 August 2005 according to S.A. Weather Services standards. The distance between fields and the weather station ranged from about 1 km to about 10 km.

The station has been recording daily values of weather elements, solar radiation, temperature and humidity at 08:00 and 14:00, as well as windrun and rainfall since 14 September 2005. The data are downloaded daily by SASRI and automatically converted, and uploaded into the ***MyCanesim*** database where reference cane evaporation (McGlinchey and Inman-Bamber, 1996) is calculated. The data can be viewed at: http://sasri.sasa.org.za/irricane/tables/index.asp.

It should be noted that due to incorrect multipliers in the data logging software, the rainfall and radiation initially recorded by the new Makhathini AWS was incorrect (over-estimated by 250% and underestimated by 20% respectively). The data and the multipliers were corrected on 17 February 2006 (radiation) and 2 March 2006 (rainfall).

The data are stored in the ***MyCanesim*** database where it is used by the Canesim model to calculate crop development, growth and water use. The simulations require a full set of weather data for the entire growing season (12 months). A weather data series was generated to fill gaps in the record using data from the SASRI automatic and manual stations at Pongola, the ARC (Institute of Soil, climate and Water of the Agricultural Research Council) automatic station at Makhathini (pers. comm. Van der Rij, Cedara) and the SASRI manual station at Makhathini. The data from these sources were adjusted using linear regressions derived from matching data series as described in Table 3.1.

Table 3.1 Deriving weather data for Makhathini from other sources.

Period	Element	Source	Adjustment
19Mar01-13Sep05	All except rain, radiation	Pongola AWS	Regress Makhathini manual vs. Pongola AWS (18 Ap97–10Oct99)
19Mar01-13Sep05	Radiation	Pongola AWS	Regress ARC Makhathini AWS vs. Pongola AWS (5 Apr 04-28 Oct 05)
19Mar01-13Sep05	Rain	Pongola manual	Regress Makhathini manual vs. Pongola manual (1Apr96–30Jun00)
14Sep05 onwards	All	Makhathini AWS	None

3.4. Soil data

Soil property data for all fields were obtained from the Pongola (J van der Merwe, pers. comm.) and Jozini (B. Nkabinde, pers. comm.) offices of the KwaZulu-Natal Dept. of Agriculture and Environmental Affairs. Pongola data were collected by Van Huyssteen *et al*. (1996). Effective rooting depth and texture data from these reports were confirmed by soil sampling and used to estimate available soil water capacity, the only soil parameter required by the ***MyCanesim*** system.

3.5. Participation by farmers and extension

3.5.1. Introduction

There were two types of project participants namely **Monitor participants** (fields where the crop, soil, irrigation and rainfall parameters were measured) and **Advice participants** (fields where advice was provided without field monitoring).

The criteria for selection for Monitor participants were:

- Acceptable irrigation system (14 day cycle or less, sprinkler spacing and type as prescribed by design, acceptable pressure).
- Acceptable crop (few gaps, good yields, few weeds, fertilised).
- Willingness and competency to record data (farmer or assistant has cell phone, visits the field daily, is literate and is willing to follow advice).
- Location (proximity to other participants).

In 2005/06 it was possible to select only eight farmers as monitor participants, four each at Pongola and Makhathini. This was because it was difficult to find suitable participants and because the workload associated with field monitoring was heavier than anticipated. After the appointment of an additional dedicated technician it was possible to visit more fields more frequently.

Hence, in 2006/07 at Pongola, nine farmers were selected (out of a group of 13 candidates proposed by extension) as monitor participants (see Table 3.2).

Participants that became unsuitable or uncooperative were removed from the group of monitor participants and replaced by new participants selected according to the criteria already mentioned.

At Makhathini, four farmers were monitored in 2005/06 (see Table 3.2). These were selected out of a larger group of candidates proposed by local leadership in the community. The situation was re-assessed during the second half of 2006. A South African Cane Farmers' database was screened for farmers that achieved cane yields of more than 70 t/ha. Twenty-three farmers were identified for thorough assessments with regard to the criteria for participation. Only Mathenjwa J and Gumbi C fulfilled the requirements. Myeni M was kept on as a monitor participant because of his leadership role in the community. Nxgongo SM and Zondo BM continue to receive advice from the system.

Table 3.2 Field and participation details of monitor participants.

Farmer name	Partici-pation start date	Partici-pation end date	Field Size (ha)	ASWC (mm)	Variety	Row Spacing (m)	Irrigation Cycle (d)	Irrigation amount (mm)
Pongola								
Mthembu D	28-May-04	3-Mar-08	9.6	90	N25	1.4	10	42
Simelane NM	01-Sep-04	3-Mar-08	11.2	50	N26	1.4	10	42
Nene TZ	06-Nov-04	7-Jan-08	10.8	120	N19	1.4	10	42
Khumalo NC	15-Dec-05	7-Jan-08	13.6	105	N19	1.4	10	42
Mncwango MT	04-Jan-05	3-Mar-08	9.5	120	N25	1.4	10	42
Phakhathi FD	08-Oct-06	4-Feb-08	11.6	120	N19	1.4	10	42
Mbokazi A	12-Sep-06	4-Feb-08	13.7	100	N25	1.4	10	42
Thabethe BE	23-Aug-06	3-Mar-08	11.8	100	N25	1.4	8	42
Ntshangase MA	24-Aug-06	19-Jun-07	13.8	90	N25	1.4	10	42
Siyaya B	6-Aug-07	3-Mar-08		90	N25	1.4	10	42
Dhlamini M	6-Jan-04	1-May-05	11.6	100	N25	1.4	10	42
Nhleko ZA	01-Sep-04	4-Aug-05	12.5	90	N26	1.4	10	42
Dube Z	02-Dec-04	29-Sep-05	11.4	120	N19	1.4	7	42
Makhathini								
Mathenjwa J	26-Jul-05	13-Jun-07		120	N19	1.2	12	36
Nxongo SM	30-Aug-05	10-Oct-06		120	N19	1.2	13	36
Zondo BM	11-Oct-05	18-Oct-06		120	N19	0.88	20	36
Myeni M	02-Dec-05	13-Jun-07		90	N19	1.2	12	36
Gumbi C	11-Oct-06	13-Jun-07		100	N19	1.4	12	36

Subscription to the service by Pongola farmers have grown from 25 in 2005, to 35 in 2006 and to 41 in November 2007 out of a possible 47 growers. This is regarded as excellent rate of uptake of a new technology. This high level of adoption was achieved by discussing the benefits of the advice to farmers at farmers' meetings, by using peers with positive experience of the service, the extension officer and project technicians to further promote service and invite farmers to subscribe. Free soil samplings were also offered to encourage farmers to subscribe.

3.5.2. Workshops and meetings

Several workshops and meetings were held during the course of the project. The aims of these were to:

- Plan, coordinate and initiate actions,
- Evaluate progress,
- Educate farmers and train project team members,
- Promote the adoption of the advice service.

These workshops were held in venues in Pongola for the Bivane small-scale sugarcane farmer scheme, in Jozini for the Makhathini sugarcane farmers and at Mount Edgecombe for agricultural advisors. Often these meetings were followed by a field visit to discuss data collection methods and cane husbandry (see Fig. 3.3 and 3.4). A summary of these meetings is provided in Table 3.3.

Figure 3.3 A visit to Mr Nene's field to discuss field recordings and irrigation scheduling with farmers, extension staff and technicians.

Figure 3.4 A visit to Ms Simelane's field to discuss field recordings and irrigation scheduling with farmers, extension staff and technicians.

Table 3.3 A summary of the various meetings held. The number in brackets indicates the number of farmers that attended each meeting.

Venue	Date	Atten-dance	Agenda
Pongola	13-Jun-05	24(18)	Introducing new subscribers to the system, attending to field monitoring problems.
	04-Oct-05	28(21)	Introducing more farmers to the system, problems with excessive drying off, problems with data collection.
	21-Feb-06	17(10)	Introducing more farmers to the system, problems with data collection.
	27-Jun-06	35(30)	Review progress, plan project operations, evaluate field and simulated data, and the practical implementation of ***MyCanesim*** advice.
	07-Dec-06	42(34)	Celebrate achievements, awards ceremony.
	05-Sep-07	130 (38)	Farmers information day: Demonstration of service to Makhahthini and Mpumalanga farmers and other role players.
	08-Feb-08	45(35)	Celebrate achievements, awards ceremony.
Jozini	09-Jun-05	10(0)	Project initiation, planning, data collection procedures.
	14-Jul-05	10(4)	Farmer education, research procedures, information collection.
	05-Oct-05	16(7)	Project procedures (collection of irrigation system information, confirming responsibilities).
	02-Dec-05	13(5)	Project procedures, inadequate irrigation systems, Final selection of farmers, farmer education. Farmer feedback.
	22-Feb-06	13(4)	Project procedures, feedback on farmer response to advice.
	28-Jun-06	15(3)	Review progress, plan project operations, evaluate field and simulated data, and the practical implementation of ***MyCanesim*** advice.
	21-Aug-07	7(0)	Convey decision to terminate field monitoring, make arrangements for Pongola farmers' day.
Mount Edgecombe	08-Sep-05	15(0)	Advisor workshop – Obtain feedback on system interface. Advisor training.

Review meetings

The main purpose of the meetings held on 27 June 2006 in Pongola and on 28 June 2007 at Makhathini was to review achievements and plan the way forward at a time when the project was at a crossroad. Hence, some elaboration is justified. The main conclusions from these meetings were:

- Progress at Pongola has been excellent with the majority of farmers on the scheme receiving advice. Although the quality of recordings has been poor and the number of monitor participants too few, both these problems are being addressed. The problem of incorrectly specified harvest dates is also being addressed.

- At Makhathini, inadequate irrigation systems and practices led to severe under irrigation. This makes the advice for water saving largely irrelevant. The project will continue but only farmers that fit minimum criteria will be accepted as participants. Current participants will be reassessed with respect to the same minimum criteria.
- Farmers from both schemes demonstrated an increased awareness of the importance of efficient use of irrigation water and this is attributed to involvement with the project and to farmers' interaction with project team members. Farmers at Pongola are particularly keen to reduce their water use in order to save costs.

Award ceremonies

Award ceremonies were held in Pongola on 7 December 2006 and 8 February 2008 to recognise the contributions of Pongola farmers and other stakeholders to this project, as well as the efforts of farmers to increase water use efficiency and agricultural productivity. Details about the awards are given in Table 3.4 and some award winners are shown in Fig 3.5.

Figure 3.5 Prize winners at the 2006 awards ceremony with an Illovo mill representative (courtesy Lloyd Phillips of Farmer's Weekly).

Table 3.4 Awards to Pongola small-scale farmers.

Award	Criteria	2005/06	2006/07
Participation (certificate)	Cooperative participation in the project for more than 9 months.	Dube Z, Khumalo NC, Mncwango MT, Mthembu D, Nene TZ, Nhleko, Simelane NM, Chiloane R (KZNDAE) and Meyer R (Illovo).	Mthembu D, Simelane NM, Nene TZ, Khumalo MC, Mncwango MT, Mbokazi NA, Thabethe BE, Ntshangase MA, Phakathi FD.
Efficient irrigation (Certificates and plaque for winner)	Use less than 1000 mm of water and achieve a cane yield of more than 95 t/ha.	Mathe CE, Mbokazi NA, Mbuyisa VO, Nkambule KO, Siyaya B; 1st prize to Mbuyisa VO for achieving a cane yield of 119 t/ha using 680 mm of water (IWUE = 17.5 kg/m^3).	KhanyeTT, Mbokazi NA, Mthembu D, Nkambule KO, Siyaya B; 1st prize to Siyaya B for achieving a cane yield of 106 t/ha using 748 mm of water (IWUE=15.8 kg.
15 ton RV club membership (Certificate)	Recoverable value yield of more than 15 t/ha.	Mbokazi NA (15.37 t/ha) and Mthembu D (16.24 t/ha).	Mbokazi NA (15.86 t/ha) and Mthembu D (15.20 t/ha).
Most improved farmer (Certificate and plaque)	Increased yield from 2004/05 to 2005/06, good agronomic practices.	Phakhati FD for a 28% increase in yield to 94 t/ha.	Simelane NM for achieving reasonable yields under severe constraints
Pongola small-scale farmer of the year (Certificate and plaque)	Excellent cane yield and quality and practising efficient irrigation, weeding and fertiliser practices.	Mthembu D.	Mbokazi NM.

Demonstration field day

A successful demonstration field day was held in Pongola on 5 September 2007 (see Fig. 3.6 and 3.7). The purpose of the day was to demonstrate to farmers and key industry representatives how the ***MyCanesim*** irrigation advice service works and how farmers can benefit from it. The hope was that it would open up the way for wider implementation of a similar service to other small-scale sugarcane irrigation schemes.

It was attended by 130 small-scale farmers and other interested persons (representatives from Transvaal Suiker Beperk, Illovo Sugar Ltd., Cane Growers' Association, and the KZN Dept. of Agriculture and Environmental Affairs) from Mpumalanga, Makhathini flats and Pongola.

Project team members explained the objectives of the project and how the ***MyCanesim*** system works. Some of the challenges and achievements were presented to the group (see Appendix 11.6). Three fields in the area were visited (Mthembu, Khumalo and Nene) and farmers explained how they participated in the project and benefited from the advice. Farmers had many questions about the irrigation systems and practices, on general cane growing practices such as row spacing, on economic issues such as water costs and yield, and on the soils. The day was ended with a braai at the Ntonga club at the Pongola Mill, where the lively interaction amongst farmers and project team members continued.

We conclude that the demonstration field day was highly successful because it was attended by a large group of farmers and other industry stakeholders, who interacted closely with local project participants. We believe that this event stimulated the curiosity of farmers from other areas and opened their eyes to the potential of irrigation scheduling to improve yields, cut costs and improve the profitability of their businesses.

3.6. Extension support

The project helped extension staff and farmers gain a much better understanding of the important factors that determined the crop water balance and how irrigation can be scheduled to impact positively on productivity and sustainability. This was made possible through regular implementation and evaluation workshops.

Figure 3.6 Project team members explain the *MyCanesim* system to small-scale farmers at Pongola.

Figure 3.7 The Pongola demonstration field day was attended by numerous small-scale farmers from Makhathini, Mpumalanga and Pongola.

The various reports available from the system (see Table 2.1) provide concrete information (albeit simulated) for extension staff to benchmark irrigation practices, growth and yield of individual fields. Examples of the irrigation advice and yield estimate reports are shown in Tables 3.5 and 3.6.

The simulated results from ***MyCanesim*** provided a good basis for discussion with farmers during field visits to identify agronomic practices that limited yields such as poor crop stand, insufficient weed control, early cessation of irrigation because sprinkler stands were too short (at Makhathini), erratic movements of sprinklers, and excessive sprinkler stand times leading to alternating periods of water logging and drought. A few examples are highlighted below.

Excessive stand times: Some farmers (Nene and Khumalo) believed that, during periods of high evaporative demand (in excess of 5 mm/d), it was more efficient to apply 90 mm per irrigation by increasing the stand time from 12 to 24 hours. This increased the irrigation cycle from 10 to 20 days. The estimated soil water deficit at the lower end of the target range was less than 90 in all cases. The consequences of this practice is that (1) a significant amount of irrigation water is wasted through run-off or deep drainage and (2) the crop is subjected to stress because extraction over the long irrigation cycle of 20 days (in excess of 100 mm) exceeds the freely available capacity. The project team explained the consequences to farmers and succeeded in convincing them to change the practices to the design specification of 12 hours stand time and a 10-day cycle.

Erratic movement of sprinklers: One farmer (Simelane) moved the line of sprinklers in an erratic pattern, thereby causing certain parts of the field to be over irrigated while other parts received too little water. It is assumed that this was done to minimise the effort required to move sprinklers. The consequences of this practice was explained to the farmer and her field assistant, who subsequently agreed to move sprinklers systematically from one end of the field to another and restart each cycle at the same end.

Table 3.5 An example of a *MyCanesim* irrigation advice report, for the 2006/07 season at Makhathini as simulated on 27 March 2007.

Field/Farmer	Currrent Action	Next Action	Start Date	Harvest Date	Dry Off Start Date	Rain Now (mm)	Irrigation Now (mm)	Yield Now (t/ha)
Mathenjwa J	Irrigating	22/MAY/07 - Stop	19-Jun-06	19-Jun-07	22-May-07	541.8	735	90
Zondo BM	Irrigating	10/JUL/07 - Stop	01-Aug-06	01-Aug-07	10-Jul-07	538.9	396	65
Ngxongo SM	Irrigating	02/JUL/07 - Stop	20-Sep-06	20-Sep-07	31-Aug-07	444.2	504	65
Myeni M	Irrigating	11/JUN/07 - Stop	15-Dec-06	15-Dec-07	25-Nov-07	263.5	288	23
Gumbi C	Irrigating	15/APR/07 - Stop	10-Mar-06	10-May-07	15-Apr-07	609.7	924	126

Table 3.6 An example of a *MyCanesim* yield estimate report, for the 2006/07 season at Pongola as simulated on 19 March 2007.

Field/Farmer	System	Irrigation Cycle (days)	Irrigation Application (mm)	ASWC (mm)	Start Date	Harvest Date	Rain at Harvest (mm)	Irrigation at Harvest (mm)	Yield at Harvest (t/ha)
Mthembu D	Overhead	9	50	91	28/06/2006	28/06/2007	816.5	1200	129
Nhleko ZA	Overhead	10	42	90	02/09/2006	02/09/2007	707.2	1134	131
Simelane NM	Overhead	10	42	50	17/07/2006	11/07/2007	812.9	1134	117
Dube Z	Overhead	10	42	120	19/12/2006	19/12/2007	680.4	1134	132
Mncwango MT	Overhead	10	42	120	11/05/2006	11/05/2007	764.5	924	124
Nene TZ	Overhead	10	42	120	19/12/2006	19/12/2007	680.4	1134	132
Nyembe MZ	Overhead	10	42	120	14/11/2006	14/11/2007	756.9	1176	130
Ndwandwe MM	Overhead	10	42	50	28/11/2006	28/11/2007	737.9	1344	122
Thabede MA	Overhead	10	42	75	15/08/2006	15/08/2007	744.7	1092	126
Nyawo BL	Overhead	10	42	70	15/10/2006	15/10/2007	708.4	1260	130
Mathe CE	Overhead	10	42	120	18/07/2006	18/07/2007	812.9	966	130
Ngwenya MK	Overhead	10	42	120	16/12/2006	16/12/2007	702.4	1134	132
Thabede DA	Overhead	10	42	120	30/11/2006	30/11/2007	737.8	1092	134
Zungu MP	Overhead	10	42	100	09/12/2006	09/12/2007	739.9	1134	130
Ntshangase LD	Overhead	10	42	50	22/09/2006	22/09/2007	713.7	1302	127
Nxumalo ZL	Overhead	10	42	50	05/10/2006	05/10/2007	700.2	1344	125
Mbuyisa VO	Overhead	10	42	100	22/12/2006	22/12/2007	594	1260	135
Ntshangase MA	Overhead	10	42	90	05/05/2006	05/05/2007	763.2	966	123
Khumalo NC	Overhead	10	42	105	13/12/2006	13/12/2007	684.3	1134	131
Siyaya B	Overhead	10	42	90	01/07/2006	01/07/2007	813.1	1008	124
Dlomo SR	Overhead	10	42	70	25/10/2006	25/10/2007	690.1	1260	128
Khanye TT	Overhead	10	42	90	05/09/2006	09/09/2007	711.1	1176	134
Malinga ME	Overhead	10	42	80	23/06/2006	23/06/2007	808.1	1050	123
Nkambule KO	Overhead	10	42	90	08/06/2006	08/06/2007	806.6	1050	124
Magagula VS Plot 485	Overhead	10	42	100	22/10/2006	22/10/2007	681.2	1176	130
Magagula VS Plot 516	Overhead	10	42	50	01/08/2006	01/08/2007	813.8	1134	123
Phakathi FD	Overhead	10	42	120	21/10/2006	21/10/2007	681.2	1176	132
Thabethe BE	Overhead	10	42	100	21/04/2006	15/04/2007	784.1	840	118
Ntshangase GJ	Overhead	10	42	120	15/08/2006	15/08/2007	744.7	1008	129
Malinga RT	Overhead	10	42	80	02/09/2006	02/09/2007	707.2	1218	131
Khumalo MH	Overhead	10	42	100	09/10/2006	09/10/2007	704.7	1134	130
Mbokazi A	Overhead	10	42	100	29/08/2006	29/08/2007	707.2	1134	131
Mamba SE	Overhead	10	42	50	04/11/2006	04/11/2007	666	1344	121
Dlamini LZ	Overhead	10	42	100	02/11/2006	02/11/2007	678.2	1176	131

Yield benchmarking: Farmers Simelane and Nene was selected as case studies to demonstrate the process of using the comparison of simulated with actual yields to identify and remedy production constraints. The yield gap was 9 and 31 t/ha for Simelane and Nene respectively. Both farmers yielded below 80 t/ha, which is economically unsustainable in the long-term. A visit by the project team (including extension staff) and farmers to the fields (see Fig. 3.8) revealed the following constraints:

- *Simelane:* The main constraint for this field is the soil. For large parts of the field the soil is extremely rocky, quite shallow and therefore has a very low water holding capacity (see Fig. 3.9). The instruments were placed in a better part of the field and at the time of the visit the state of the cane in this area was markedly better (taller and greener) than the rest of the field. The yield gap is attributed to the fact that a large part of the field has a lower water holding capacity than the monitored and modelled section of the field. Ms Simelane was advised to halve her stand time from 12 to 6 hours thereby applying less water (21 mm as opposed 42 mm) per irrigation but irrigating more frequently if required (every 5 days instead of every 10 days). A trash blanket will reduce soil evaporation and make more water available to the crop.

Figure 3.8 Extension field visit to investigate agronomic problems in the field of Ms Simelane of Pongola.

Figure 3.9 Severely stressed sugarcane growing on a part of Ms. Simelane's field with very shallow and rocky soil.

- *Nene:* Several factors contributed to the under-performance of the crop on Mr Nene's field. The most important one was a blocked drain that caused intermittent waterlogging in parts of the field. His response to waterlogging was to shut down the irrigation of the entire field. Prolonged under-fertilisation and poor weed control also contributed to the poor yields. Nene was advised to correct weeding and fertiliser practices, to clear the drain and to stop irrigation only in those areas of the field that were affected by waterlogging. The rest of the field should receive irrigation as advised by the ***MyCanesim*** system.

The full report on these two field visits is given in Appendix 11.5.

3.7. Challenges

Several challenges were encountered during the implementation of the service in Pongola and Makhathini. A few are highlighted here.

Data collection and feedback

The quality of field data collected before June 2006 was unacceptably low for most fields and it was clear that a different approach was needed. Weekly (instead of fortnightly) visits by SASRI technicians after June 2006 ensured better quality of rainfall, irrigation and wetting front detector response data. The quality of data for the 06/07 season should be acceptable.

For Makhathini, data quality was problematic. Despite repeated attempts, it seemed impossible to obtain reliable cane delivery data, harvest schedules and water use data from the relevant organisations. Historical yield data also seemed unreliable. For Pongola, these data were available and although some checking and correction was required, the quality was generally acceptable.

The validity of irrigation advice depends on feedback from farmers when they deviated from prior advice for whatever reason. Although the project team educated farmers to understand the importance of their feedback and how to use the reply path facility, they seldom did. This, and the delay in getting measured irrigation data into the system (particularly initially), sometimes caused advice to be irrelevant or incorrect. The delays in getting the data into the system have been reduced considerably as project operations have been streamlined.

Inadequate irrigation systems

It is clear that the poorly maintained irrigation systems at Makhathini did not cope with crop demand and that there was little opportunity for saving water (see section 4.2). Farmers were unable to apply the required amount of water due to too few sprinklers (resulting in too lengthy irrigation cycles) or short sprinklers (irrigation ceased as soon as cane is taller than sprinklers, see Fig. 3.10). The impact of the inadequate systems on yield and income was quantified using ***MyCanesim*** and discussed with participating farmers and other role-players. Lack of land ownership, cash flow problems and the 12-hour per day water supply are severe limitations to correcting these problems. Currently, only two farmers could be found that fulfilled the criteria set for project participation.

Figure 3.10 Inadequate irrigation sprinklers in Makhathini. Short sprinkler stands cannot be used to irrigate tall sugarcane.

Drying off advice

System evaluation showed that the advised date of the last irrigation was too late, compared to the rule of Donaldson and Bezuidenhout (2000) on which it was based. Farmers generally did not agree with the advice and dried off for at least 30 to 60 days. This discrepancy was due to a coding error, which was corrected in February 2007. Another practical challenge was that the harvesting schedule was continually changed, at short notice, rendering irrigation advice irrelevant. This was addressed by automatically reminding farmers and their agents by SMS to confirm harvest dates, eight weeks prior to the last known date of harvest. In addition, weekly meetings were held in Pongola between mill staff and harvesting contractors to obtain up-to-date harvest schedules. Harvest schedules could not be obtained at Makhathini.

Advice after rain

Another practical problem was the frequent delay in getting advice out to farmers to stop irrigation after good rains. This was due to (1) a one-day delay in post-midnight rainfall data entering the database, or (2) system downtime due to hardware failures (weather station, computer or cellular network problems) or weekend software crashes. A re-scheduling of daily computing jobs to minimise computing bottlenecks and optimisation of routine network and database maintenance, alleviated the problem to some extent. However, advice to stop irrigating after significant rains still reaches the farmers one or two days after the event and farmers appear to stop irrigating after good rains by themselves. The later advice serves as confirmation of their actions.

Pump control

A challenge at Pongola was that that the majority of farmers share pumps, and the associated costs, with one or two neighbours. When all members of a pump group were not subscribed to the service, or did not receive similar advice, it often created conflict and non-adherence to the advice. The system will be adjusted to allow for synchronisation of advice to members of a pump group, when the development stage of the different fields is similar enough to allow it.

Access to technology

Internet and fax access proved problematic for stakeholders based in rural areas. The fax machine of the Department of Agriculture in Pongola has not been operational for more than two years during the project and the technician had to rely on SASRI to obtain copies of the advice summaries. Low bandwidth Internet access (dial-up modem) made it very difficult to use the system user interface efficiently. Internet access was not available in Makhathini. This can be addressed soon as high speed Internet access becomes more affordable. Cell phone coverage and ownership were not limiting factors in both study areas. Generally, sufficient capacity existed to use cell phones for receiving and reading SMSs. The few farmers who did not know how to read and manage SMSs on their phone, were shown how to do so.

3.8. Conclusion

The *MyCanesim* system was implemented fully on the Pongola small-scale irrigation scheme. Subscription to the service grew steadily from 5 in 2005 to 41 in 2008. Implementation at Makhathini was problematic and initially only five fields were monitored and received advice in 2005/06. However, only two farmers out of the twenty-three that were subsequently evaluated, fulfilled the criteria for monitor participants, and in 2006/07 only two fields were monitored. The main stumbling blocks were inadequate irrigation systems and the unavailability of quality data at field and scheme level. Other challenges experiences at both schemes included obtaining quality irrigation and rainfall data, and unreliable fax and inadequate Internet access for extension staff.

The project showed that regular and meaningful interaction between project technicians or extension staff and farmers are crucially important to maintain enthusiasm and assist with interpretation and practical implementation of advice.

The project helped extension staff and farmers gain a much better understanding of the important factors that determined the crop water balance and how irrigation can be scheduled to impact positively on productivity and sustainability. The various reports available from the system provide concrete information (albeit simulated) for extension staff to benchmark irrigation practices, growth and yield of individual fields. The simulated results provided a good basis for discussion with farmers during field visits to identify agronomic practices that limited yields.

4. FIELD EVALUATION

4.1. Introduction

The aims of this part of the project were (1) to expose the system to the practical aspects of farming in order to refine it if necessary, (2) to evaluate the accuracy of the system to predict crop growth and water use, and (3) to evaluate the ability of the system to provide useful advice. Field evaluation also served to create awareness amongst farmers about the importance of irrigation scheduling and to pave the way for wider implementation in the SA sugar industry.

4.2. Methods

4.2.1. Measurements

A number of farmers in each scheme were selected to take part in the field evaluation (see Table 3.2). An area of approximately 5 m x 1.4 m was selected in each of four fields in 2005/06 and nine fields in 2006/07, to measure irrigation plus rainfall (two gauges) and wetting front detector response. The latter was measured by two wetting front detectors (Stirzaker, 2003) at 50 cm depth. Initially participants were asked to record irrigation plus rainfall and wetting front depth on a daily basis on preformatted data sheets. It soon became apparent that the reliability of data collected this way was questionable. An additional technician fully dedicated to this project was appointed in November 2005 and allowed more frequent field visits. Since January 2006 these measurements were conducted weekly by project technicians. Furthermore in July 2007, eight rain gauges were installed in areas outside cane fields to enable more reliable disaggregating of rainfall and irrigation.

Instrument installation and demonstration to participants are depicted in Fig. 4.1 to 4.3.

Figure 4.1 Installation of wetting front detectors and explaining how to interpret responses from it.

Figure 4.2 Measurement of irrigation and rainfall in Mr Mthembu's field.

Figure 4.3 Makhathini participants are shown how to capture rainfall and irrigation data as well as wetting front detector responses.

Crop status was assessed by measuring stalk height and population (three reps of 6 m row sections each), while canopy interception of photosynthetic active radiation (named canopy cover, CC) was measured periodically (weather permitting) with a SF-80 ceptometer (Decagon Devices, Pullman, WA, USA, 10 reps in the sampling area). Where possible final yield was also estimated by weighing the millable cane from three 6 m row sections, just before the field was harvested.

4.2.2. Simulations

Input data

Input data for simulations are given in Table 4.1. Recorded irrigation data was used to adjust input data for simulations as soon as it became available. Due to the unreliability of field recorded rainfall data, the rainfall recorded by the automatic weather station was used for all simulations.

Table 4.1 Field details of Pongola and Makhathini monitor participants.

Farmer name	Field Size (ha)	ASWC (mm)	2005/06 Start date	2005/06 Harvest date	2006/07 Start date	2006/07 Harvest Date	Var	RS (m)	Irr Cycle (d)	Irr amount (mm)
Mthembu D	9.6	90	30May05	26Jun06	27Jun06	28Jun07	N25	1.4	10	42
Simelane NM	11.2	50	13Aug05	20Jul06	24Jul06	16Jul07	N26	1.4	10	42
Nene TZ	10.8	120	05Dec05	13Nov06	13Nov06	10Dec07	N19	1.4	10	42
Khumalo NC	13.6	105	15Nov05	07Dec06	10Dec06	12Dec07	N19	1.4	10	42
Mncwango MT	9.5	120	11May05	11May06	20May06	05Apr07	N25	1.4	10	42
Phakhathi FD	11.6	120	22Oct05	08Oct06	10Oct06	05Oct07	N19	1.4	10	42
Mbokazi A	13.7	100	27Jul05	30Aug06	02Sep06	25Aug07	N25	1.4	10	42
Thabethe BE	11.8	100	15May05	15May06	17May06	24Mar07	N25	1.4	8	42
Ntshangase MA	13.8	90	15Apr05	15May06	20May06	14Jun07	N25	1.4	10	42
Siyaya B			15Sep05	12Sep06	12Sep06	15Jul07				
Mathenjwa J (A)		120	16Jun05	10Jul06	19Jul06		N19	1.2	12	36
Mathenjwa J (B)		120	30Jun05	10Jul06	19Jul06		N19	1.2	12	36
Nxongo SM		120	24Jul05	11Sep06			N19	1.2	13	36
Zondo BM		120	21Aug05	14Aug06			N19	0.88	20	36
Myeni M		90	2Nov05	08Dec06	17Jan07		N19	1.2	12	36
Gumbi C		100			10Mar06	11Apr07	N19	1.4	12	36

Simulation accuracy

Observations in Pongola were used to assess the accuracy of system simulations and advice, as well as the extent to which farmers followed the advice. Makhathini data were regarded as too incomplete and unreliable to be used for this purpose.

WFD observations were used to assess the ability of the model to simulate soil water status. The following method and assumptions were used: It was assumed that the wetting front would reach a depth of at least 50 cm (named WFD50 event) when simulated available soil water content (ASW) increased with at least 5 mm/d to a value of more than 80% of the available soil water capacity (ASWC), or when simulated ASW increased by more than 50 mm/d. An index of agreement between simulated and recorded soil water status was calculated as the number of correctly simulated WFD50 events (when a WFD50 event was recorded within a week after the simulated event), divided by the sum of the number of correctly simulated WFD50 events, number of over estimates (when a simulated WFD50 event was not recorded) and the number of under-estimates (when a recorded WFD50 event was not simulated).

CC and CY data were also used to assess the accuracy of model simulations by statistically comparing measured and simulated data.

The validity of advice generated by the system was assessed by comparing advice with ASW simulated from actual irrigation records. Advice not to irrigate was deemed incorrect when the ASW for that day was below 50% of ASWC, while advice to irrigate was deemed incorrect when ASW of that day or of the next three days remained above or equalled ASWC. These rules did not apply during the drying off period. Advice validity was quantified by dividing the number of days with incorrect advice with the total number of days in the growing season.

Adherence to advice was quantified by counting the number of unadvised irrigations (UI), unadvised stops (US) and advised irrigations (AI) for each field and each growing season. The adherence score (AS in %) was then calculated as:

$$AS = 100\ (1 - (UI + US)/AI) \qquad \text{Eq. 1}$$

An AS value of 100% implies that the farmer followed the advice exactly while a score of 0 implies that the farmer executed a number unadvised actions equal to the number of advised irrigations.

4.3. Pongola results

4.3.1. Rainfall and irrigation input data

The performance of the system to accurately simulate crop growth and water status depends on the reliability of input data.

Field recorded rainfall sometimes varied considerably between farmers and was also sometimes different from weather station recorded rainfall. Although some of this is attributed to real spatial variation in rainfall, the initial methodology of recording field rainfall was not entirely appropriate (farmers recorded, biweekly visits by technicians) and brings doubt to the reliability of some of the data. Variability in rainfall between fields decreased after technicians recorded rainfall weekly and after dedicated rain gauges were installed in July 2007 (see Fig. 4.4). The average standard deviation decreased from 6.1 to 4.4 mm per weekly sample.

Seasonal totals of field-recorded rainfall are compared with seasonal totals of weather station recorded rainfall in Table 4.2.

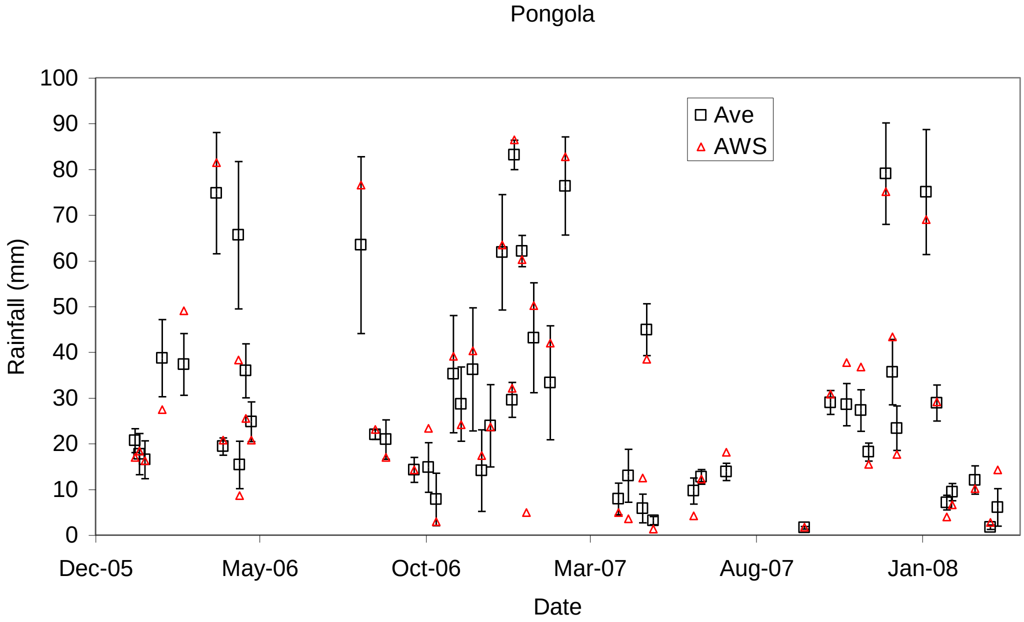


Figure 4.4 Daily rainfall totalled over sampling periods (typically one week) and then averaged over all fields with active monitoring at the time plus the weather station (Ave) compared to weather station recorded rainfall (AWS). The average is shown as a marker and the standard deviation as a bar (2 x stdev).

The difficulty in obtaining reliable and timeous rainfall data justified the decision to use rainfall data from the weather station for simulations. This data is of higher quality (reliable, higher resolution and immediately available) and results shown in Fig. 4.4 suggest that the spatial variation on the Pongola scheme is likely to have a very small impact on scheduling advice.

In many instances it took weeks and even months to identify and rectify incorrect recordings or incorrect disaggregation of irrigation and rainfall. This affected the accuracy of simulations and the validity of the advice generated from it (see section 4.3.6), as these depended on accurate irrigation histories at the time.

Irrigation water use measured by flow meter (IWU_{Flow}) was compared to that measured by two gauges in the monitoring area in each field (IWU_{Gauge}), and found to differ (see Table 4.2). These differences were inconsistent in 2005/06, but in 2006/07 IWU_{Flow} exceeded IWU_{Gauge} considerably. Differences were relatively larger for low IWU values (Ntshangase and Mcwango). Flow meters record IWU before any conveyance or application losses while field rain gauges measure irrigation that the crop receives at the top of the canopy. WU_{Flow} is therefore expected to exceed IWU_{Gauge}. There are probably other factors that also contribute to these differences, such as different application rates and schedules applied in the monitoring area compared to the rest of the field, incorrect exposure of gauges (below canopy or not level), and incorrect recordings of gauges or flow meters (misread or computerised incorrectly) etc.

Table 4.2 Seasonal irrigation water use totals (mm) as measured by gauges in the field or by flow meter and seasonal rainfall totals (mm) as recorded by the weather station (and used in the simulation) or measured by gauges in the field. The seasonal average amount of irrigation measured per application (mm) is also given.

Season	Farmer	IWU				Rainfall	
		My Canesim	Field rain gauge	Flow meter	Irrigation amount	***MyCanesim***	Measured
2006/07	Mthembu D	682	682	1125	34	801	693
	Simelane NM	548	548	875	39	810	776
	Thabethe BE	321	237*	556	24	658	666*
	Mncwango MT	148	148	512	30	738	560
	Ntshangase MA	102	102	308	17	790	649
	Phakathi FD	551	551	669	37	650	410
	Mbokazi A	534	534	924	45	703	595
	Khumalo NC	576	576	552	44	863	649
	Nene TZ	557	557	652	43	841	480
	Ave	446	437	686	35	762	609
2005/06	Mthembu D	1424	1469	1202	54	511	460
	Simelane NM	868	877	823	63	495	507
	Khumalo NC	570	570	743	52	685	622
	Nene TZ	934	925	753	58	602	614
	Ave	949	960	880	57	573	551

* Full growing season was not monitored

In ***MyCanesim*** simulations it was assumed that 42 mm was applied with each irrigation. Actual irrigation depths exceeded this amount by 35% in the 2005/06 season (Table 4.2), while it was on average 16% lower than assumed 42 mm in 2006/07. Actual irrigation depths in 2006/07 were within 10% of the assumed amount of 42 mm for four of the nine fields. We conclude that it seems more important for accurate simulations to know when and if irrigation took place, than the actual amount.

4.3.2. Simulation accuracy: Soil water balance

The progression of the simulated water balance for individual fields are illustrated in Fig. 4.5 to 4.12 and compared to measurements of rainfall, irrigation and soil water status.

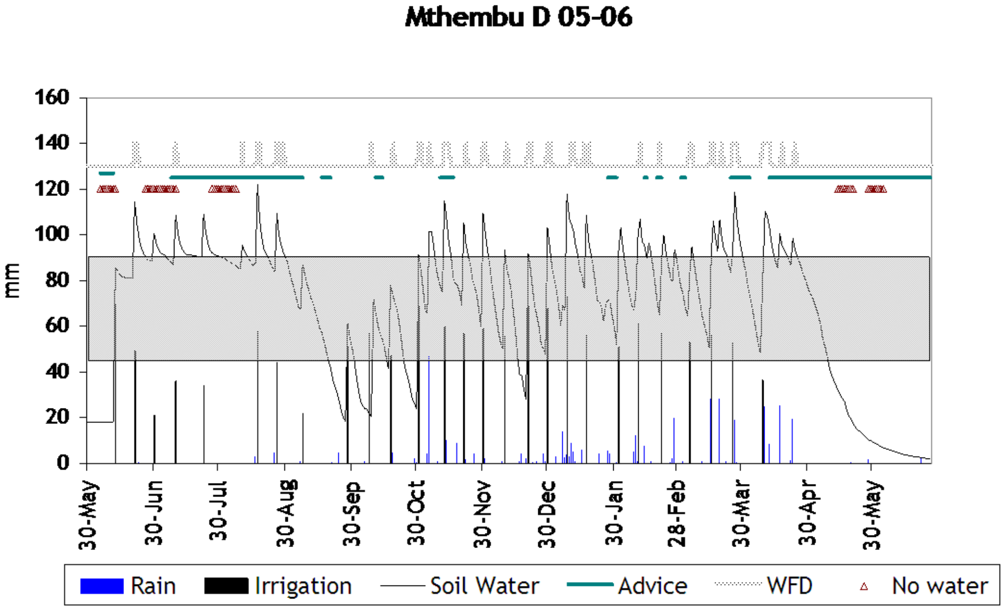
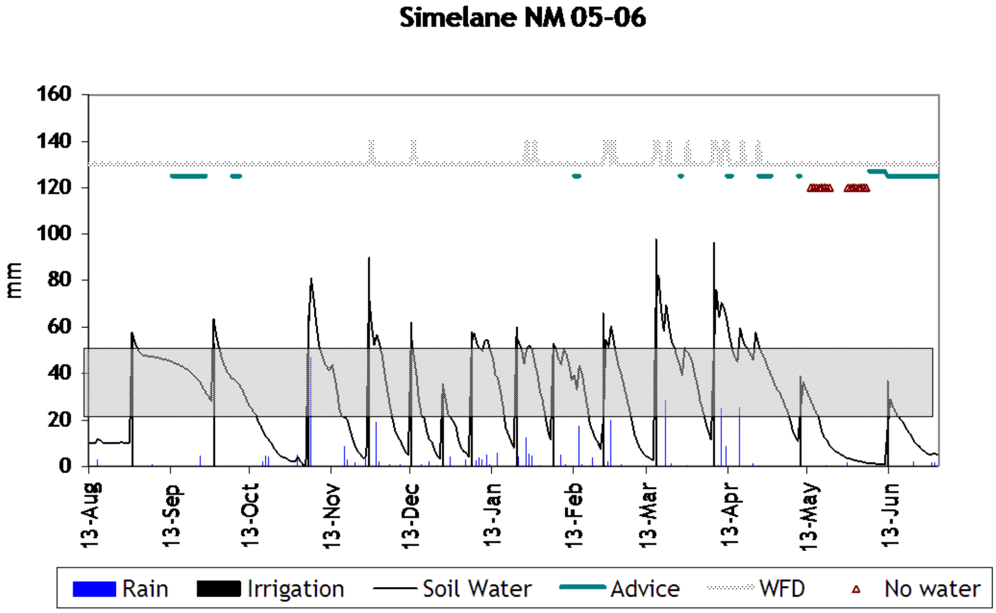


Figure 4.5 The simulated water balance for farmer Mthembu for the 05/06 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether none (no blip), one (half a blip) or both (full blip) wetting front detectors (WFD, topmost light line) indicated a wetting depth of at least 50 cm.



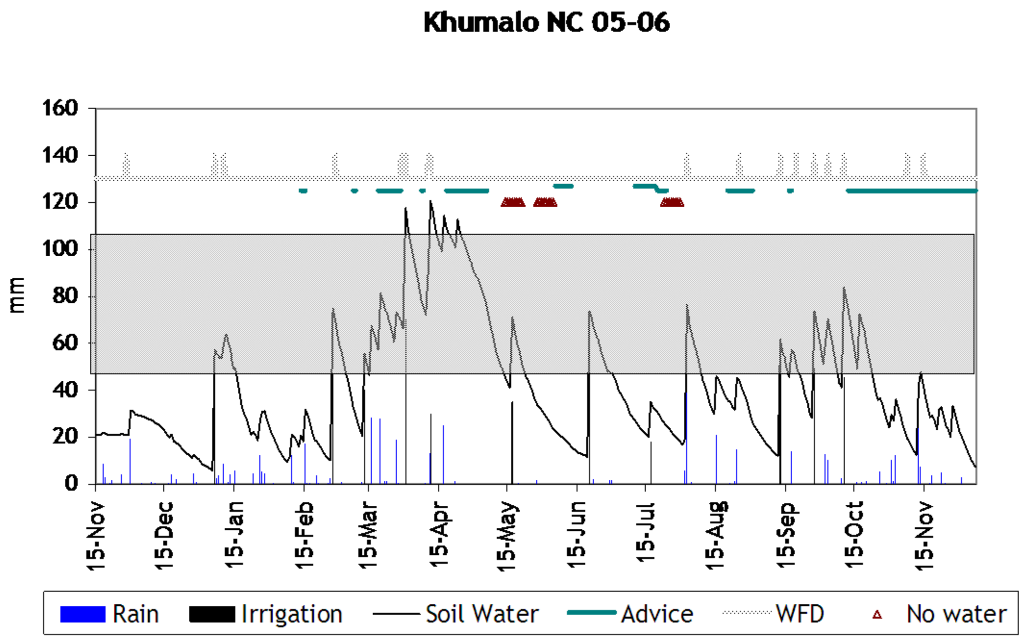


Figure 4.6 The simulated water balance for farmers Simelane and Khumalo for the 05/06 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

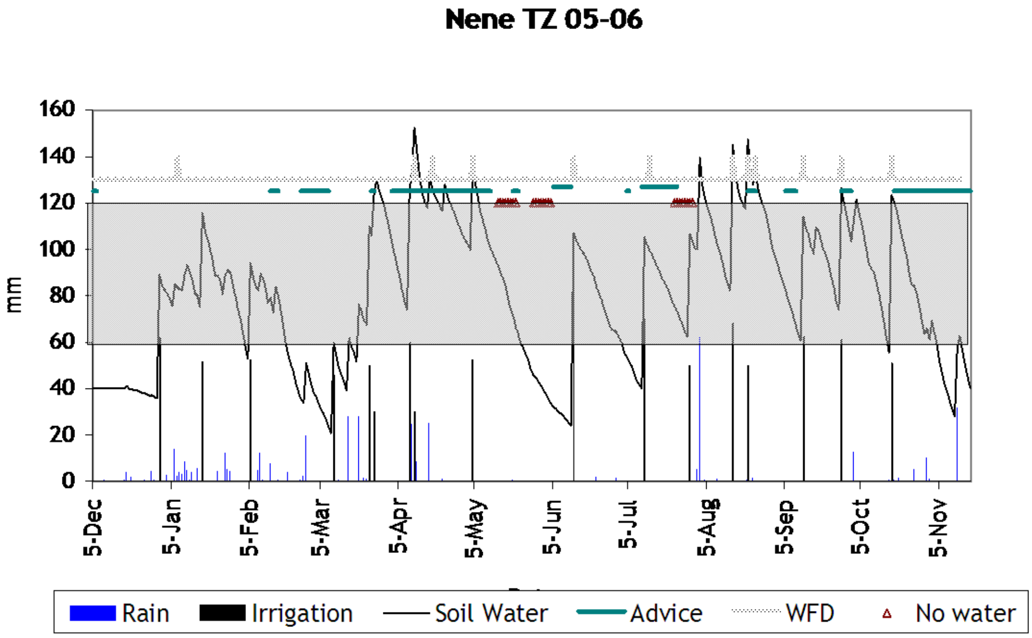
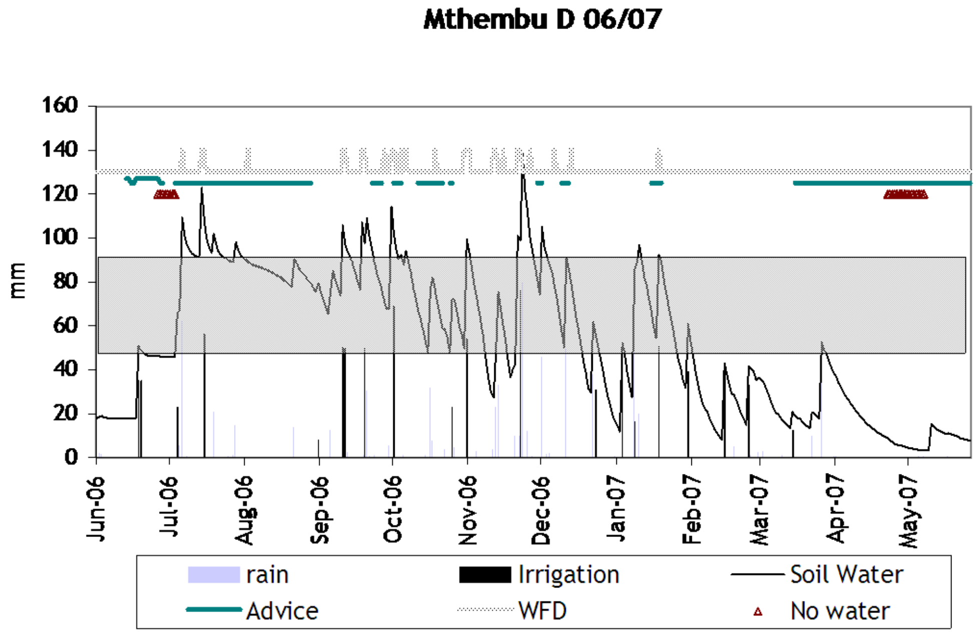


Figure 4.7 The simulated water balance for farmer Nene for the 05/06 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.



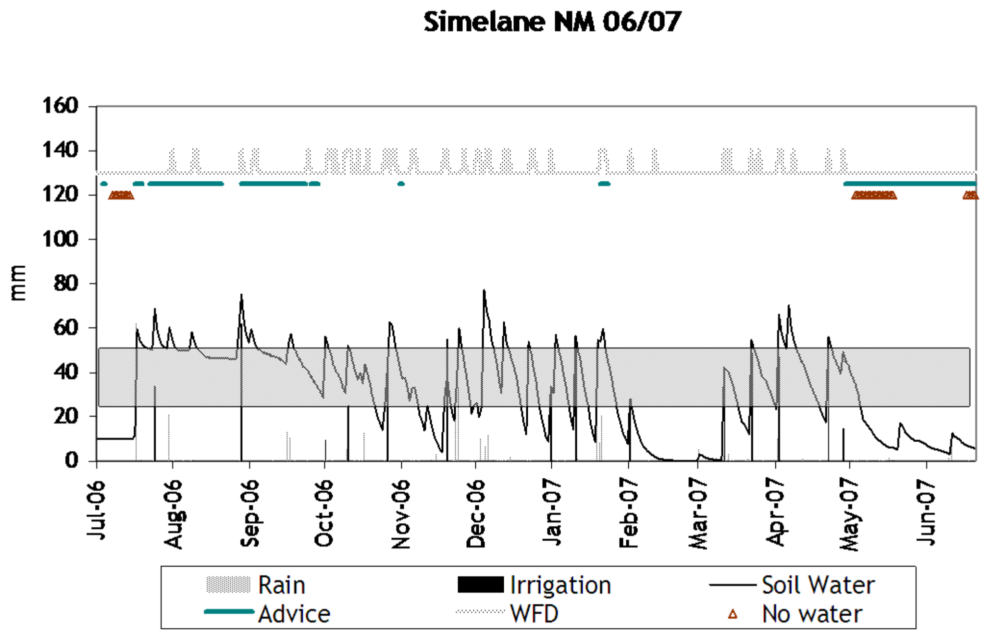
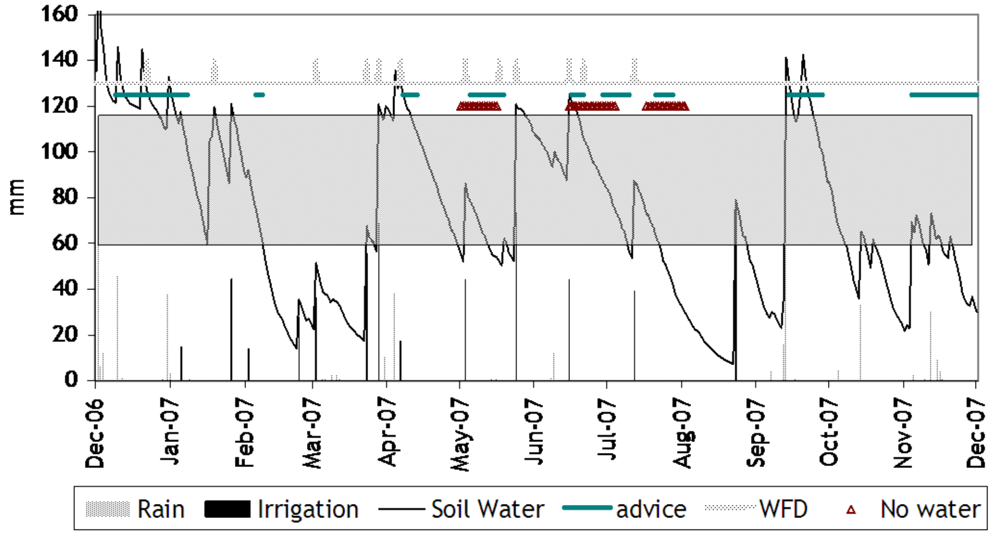


Figure 4.8 The simulated water balance for farmers Mthembu and Simelane for the 06/07 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

Nene TZ 06/07



Mncwango MT 06/07

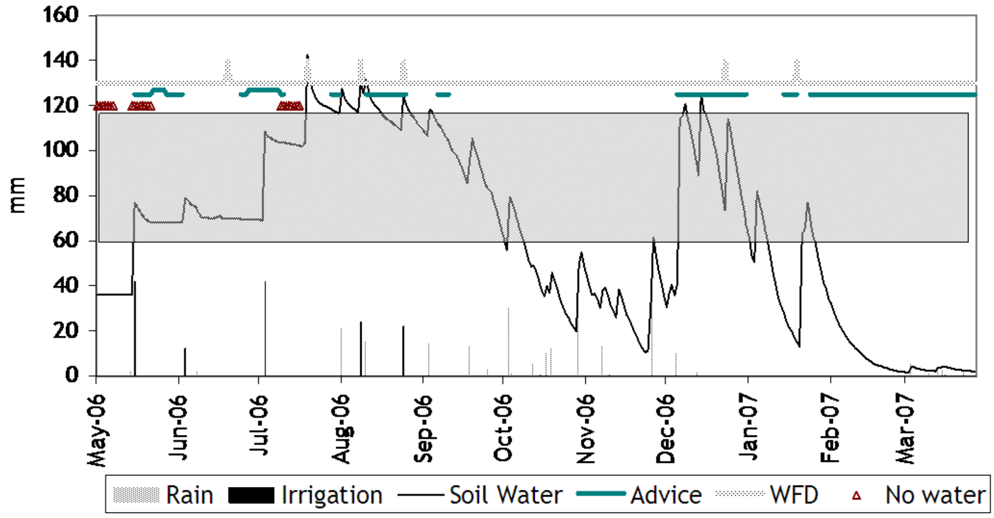
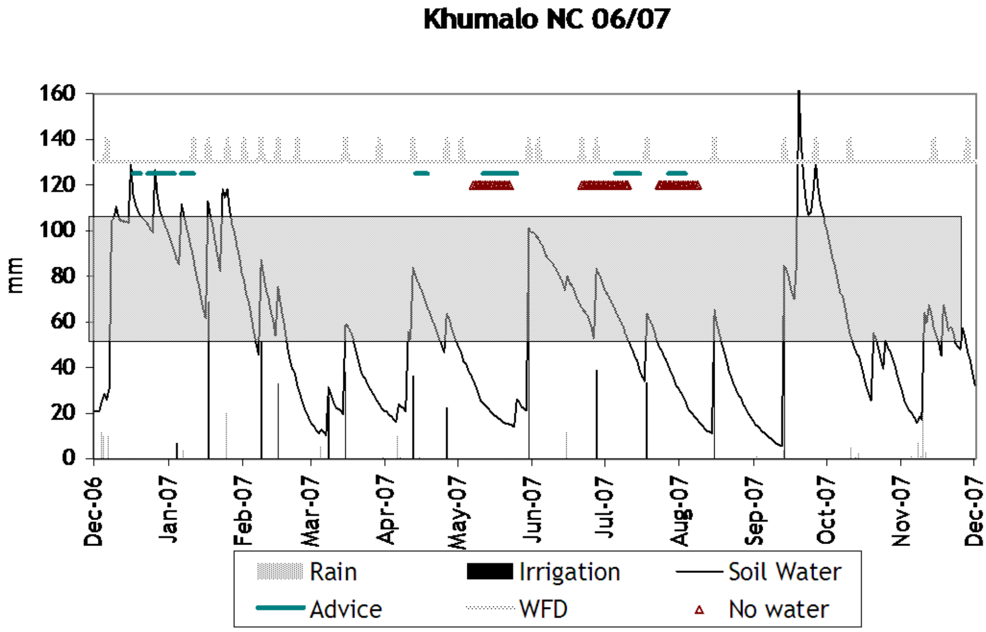


Figure 4.9 The simulated water balance for farmers Nene and Mcwango for the 06/07 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.



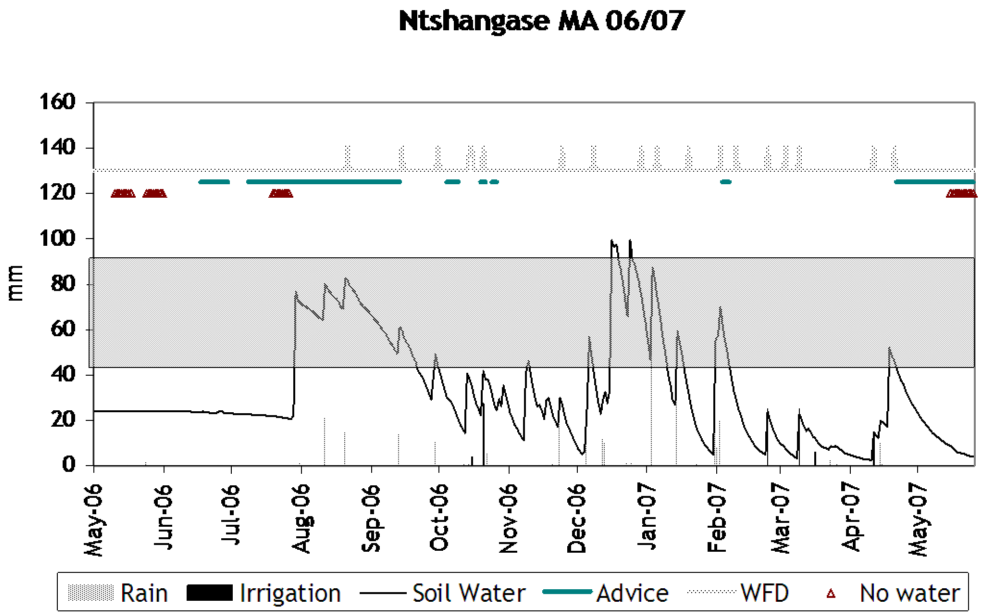


Figure 4.10 The simulated water balance for farmers Khumalo and Ntshangase for the 06/07 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

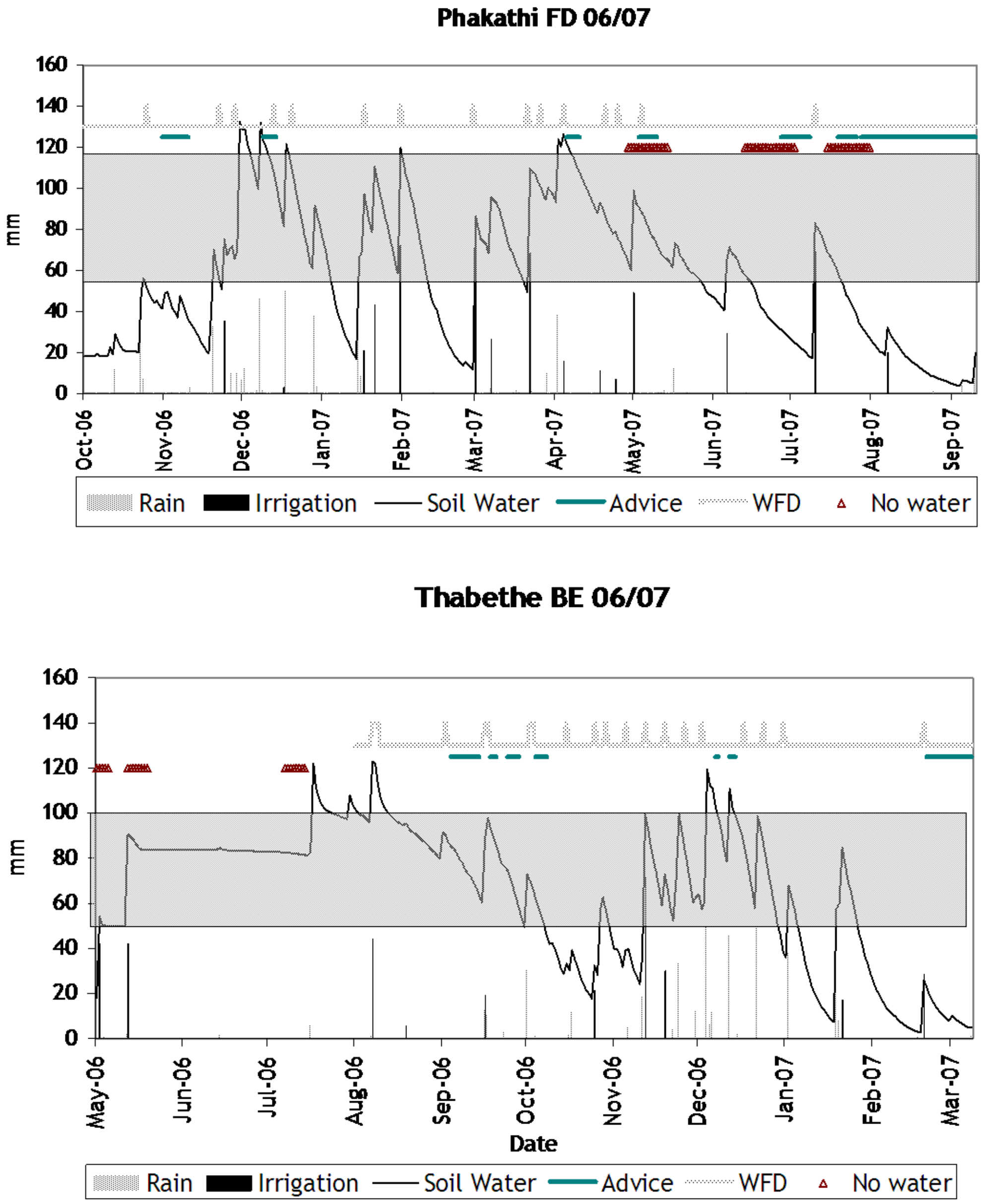


Figure 4.11 The simulated water balance for farmers Phakathi and Thabethe for the 06/07 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

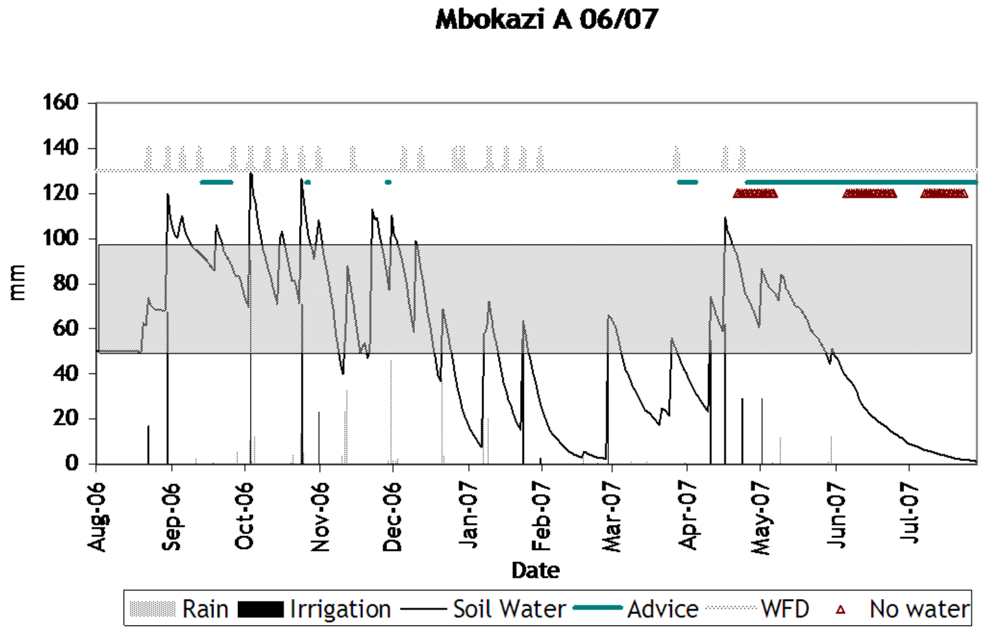


Figure 4.12 The simulated water balance for farmers Mbokazi for the 06/07 season. The graph shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line), when no water was available (third from top horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

Wetting front detector responses were used to assess the ability of the model to simulate soil water status. Results are shown in Table 4.3.

The accuracy of soil water status simulations was acceptable (IA of more than 50% and a difference between the number of over and under-estimations of less than 6) for 4 fields in 2006/07 and 2 fields in 2005/06. In 2006/07 the model tended to under-estimate soil water status for field with a very low ASWC (e.g. Simelane), when very little water was applied (e.g. Mncwango, and Ntshangase), and in poorly drained fields (Khumalo). In 2005/06 the model tended to over-estimate soil water status for Khumalo and Nene. This could possibly be due to doubtful quality of recordings at the start of the season when recording procedures were still being established.

Further investigation is required to identify appropriate model refinements.

Table 4.3 The number of instances that the soil water status was correctly simulated (Hits), over-estimated and under-estimated, and the index of agreement (IA) between simulated and actual wetting front depths of at least 50 cm. The available soil water capacity (ASWC) and seasonal total irrigation (IWU) are also given. See text for further explanation.

Season	**Farmer**	ASWC (mm)	IWU (mm)	Hits	Over	Under	IA (%)
2006/07	Mthembu D	90	682	20	4	6	67
	Simelane NM	50	548	23	4	16	53
	Thabethe BE	100	321	8	3	12	35
	Mncwango MT	120	148	4	8	2	29
	Ntshangase MA	90	186	5	4	13	23
	Phakathi FD	120	551	14	3	1	78
	Mbokazi A	100	534	14	4	8	54
	Khumalo NC	105	576	10	3	14	37
	Nene TZ	120	557	10	8	2	50
	Ave		456	12	5	8	47
2005/06	Mthembu D	90	1401	30	5	10	67
	Simelane NM	50	789	13	9	4	50
	Khumalo NC	105	497	6	3	11	30
	Nene TZ	120	935	12	10	0	55
	Ave		949	15	7	6	50

4.3.3. Simulation accuracy: Canopy cover

Simulated and observed values of canopy cover are compared in Fig. 4.13 to 4.15.

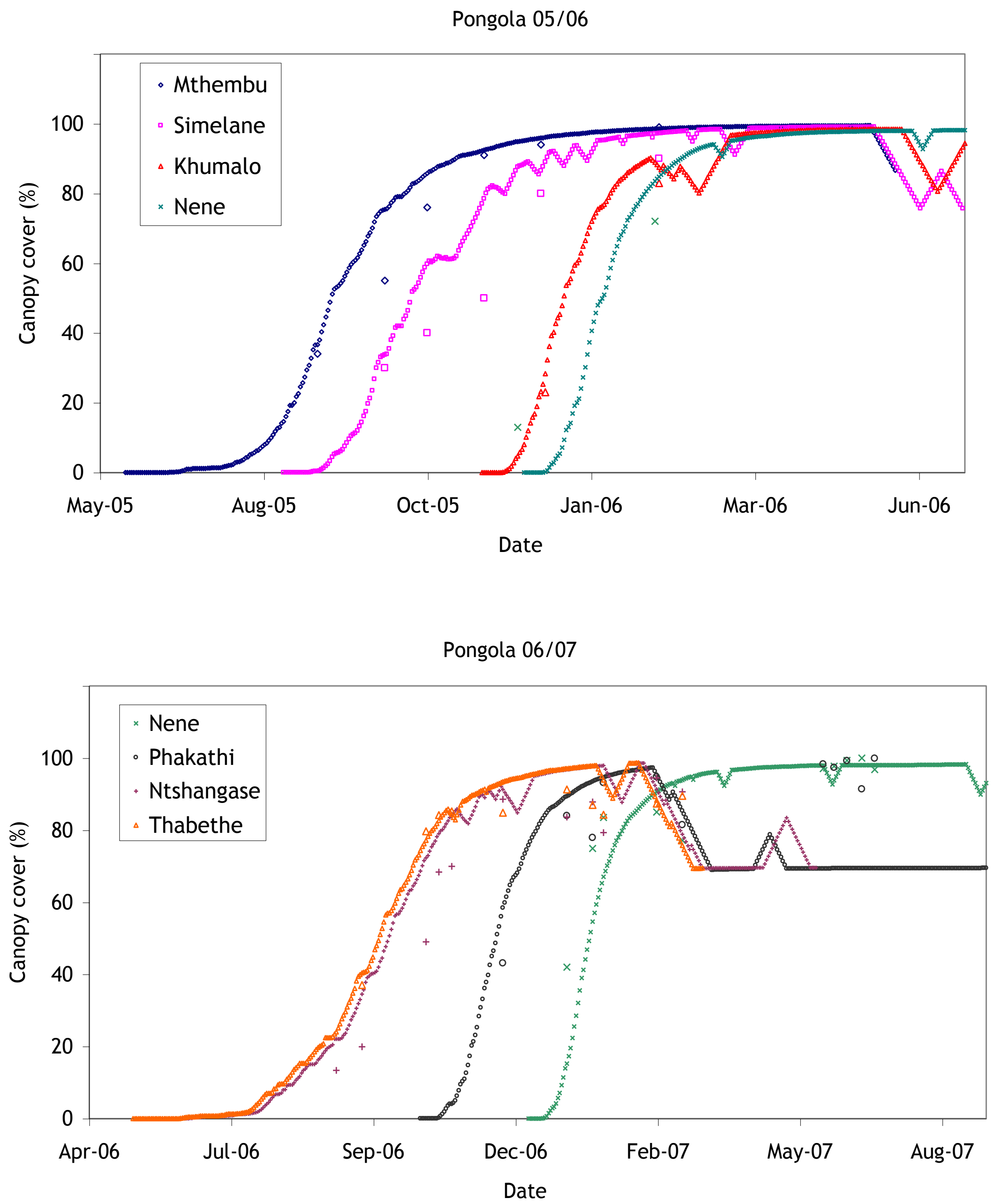


Figure 4.13 Simulated (lines) and measured (markers) canopy cover for the 05/06 season and for selected farmers for the 06/07 season in Pongola.

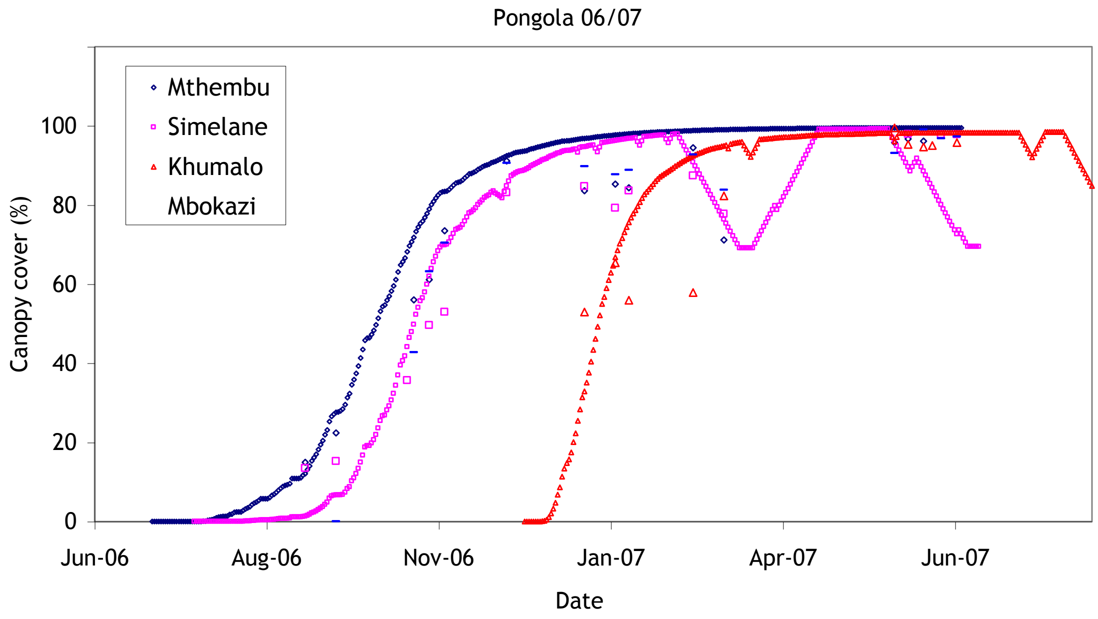


Figure 4.14 Simulated (lines) and measured (markers) canopy cover for selected farmers for 06/07 seasons in Pongola.

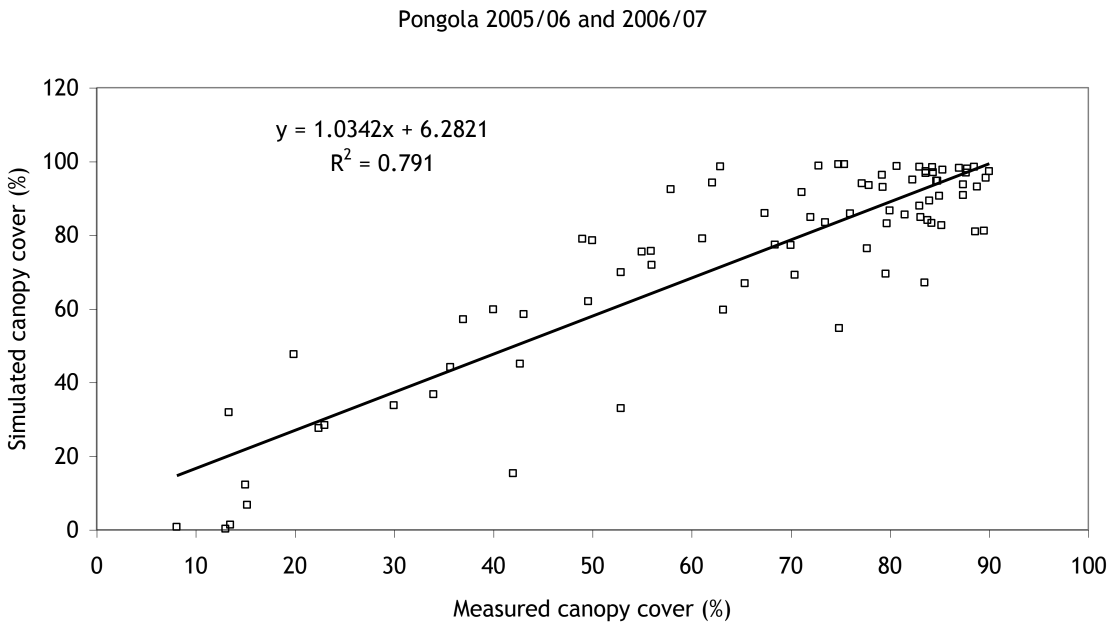


Figure 4.15 Simulated and measured values of canopy cover over two seasons and from all fields. The regression between simulated and observed values is shown. Only data pairs for observed values below a canopy cover of 90% were included.

Overall, simulation error was within acceptable levels (root mean square error = 15%, Mean bias error = +3%, n=122). Agreement between simulated and observed values was exceptionally good for most fields. Generally, it can be concluded that Canesim model simulates canopy cover with sufficient accuracy for the purposes of estimating crop water use and calculating irrigation schedules.

4.3.4. Simulation accuracy: Yield

Apart from two exceptions (Nene in 2005/06 and Mbokazi in 2006/07) simulated and observed yields compared favourably (see Table 4.4). The root mean square error (RMSE) for all data is 16 t/ha, which is satisfactory. The RMSE reduces to 10 t/ha (R^2=0.7) when these two cases are excluded from the analysis.

Field sampled yields are often quite different from yields calculated from mill deliveries. The method of sampling used here is regarded as inadequate and sample size and number needs to be increased to accurately reflect field average yield.

Stalk length and population are two yield components that could shed more light on discrepancies between simulation and measured yields. Stalk length was very low for Ntshangase in 2006/07, and Khumalo and Nene in 2005/06, confirming that poor growing conditions caused low yields. Stalk population was low for Simelane and Mbokazi in 2006/07 and Simelane in 2005/06. Although Simelane grew a low population cultivar (N26), the stalk population is too low to ensure break-even yields. The farmer should reconsider a replant. The high measured yields and stalk length contradict the low measured stalk population. It is suspected that the stalk population in the sampling area may not have been representative of the whole field.

Table 4.4 Simulated yields compared to yields estimated from mill deliveries and from a field sample. Measured stalk length and population at harvest are also given.

Season	Farmer	Cane Yield (t/ha)			Stalk	
		My Canesim	Mill measured	Field sampled	Length (cm)	Pop (m^2)
2006/07	Mthembu D	95	112	102	192	11
	Simelane NM	86	73	115	208	5
	Thabethe BE	79	81	111	198	19
	Mncwango MT	70	81	NA	NA	NA
	Ntshangase MA	72	74	81	168	19
	Phakathi FD	95	89	86	218	16
	Mbokazi A	88	116	136	230	7
	Khumalo NC	97	NA	80	182	13
	Nene TZ	103	NA	104	208	16
	Ave	87	90	102	201	13
2005/06	Mthembu D	112	126	168	234	17
	Simelane NM	80	72	116	222	9
	Khumalo NC	95	91	96	175	14
	Nene TZ	113	79	70	161	13
	Ave	101	92	112	198	13

NA – Not available

4.3.5. Observed crop growth

Measured stalk population and height for the 05/06 and 06/07 seasons are shown in Fig. 4.16 to 4.19.

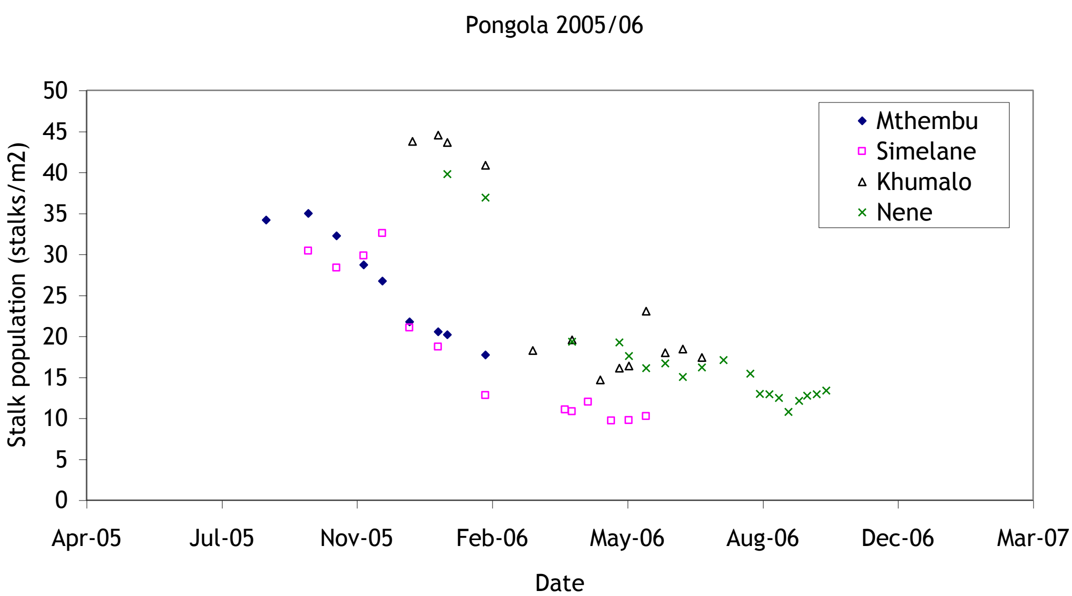
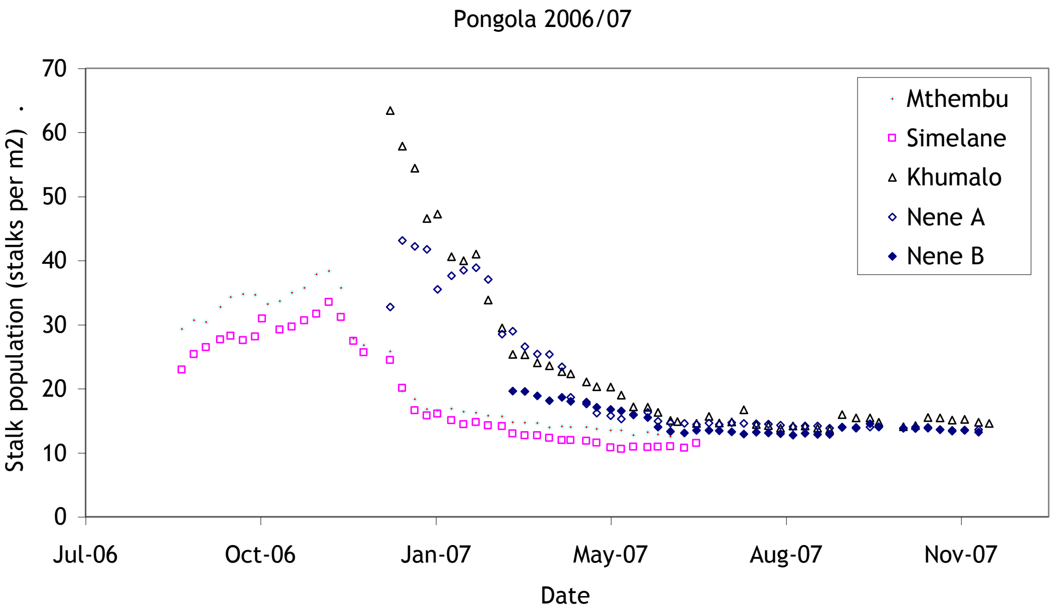


Figure 4.16 Measured stalk population for the 05/06 season at Pongola.



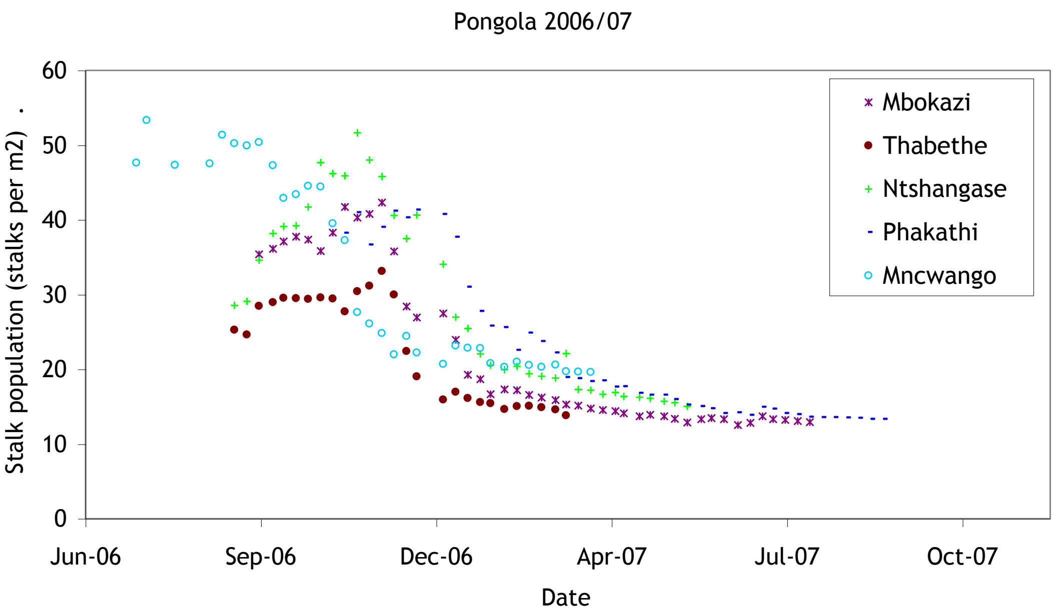
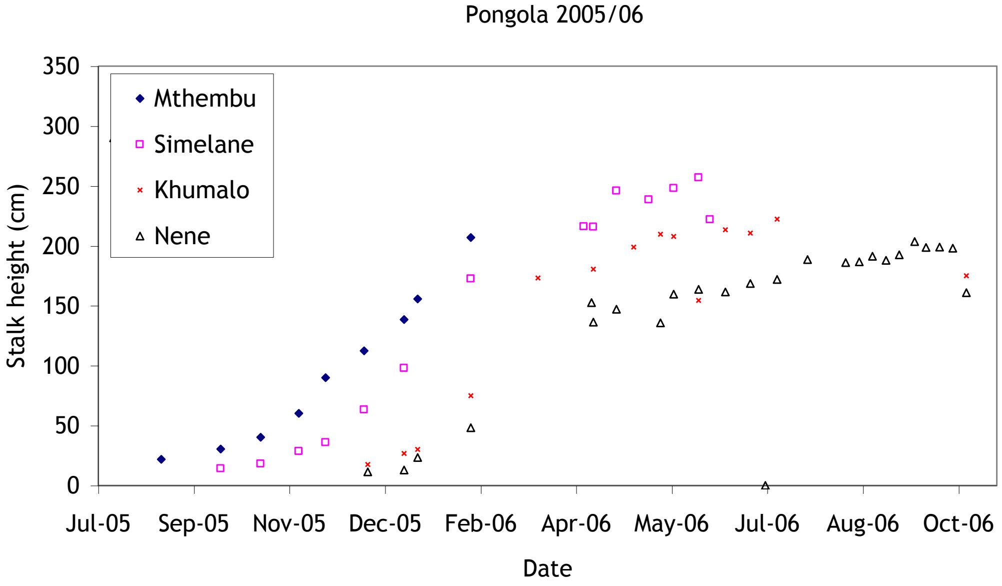


Figure 4.17 Measured stalk population for the 06/07 season at Pongola.



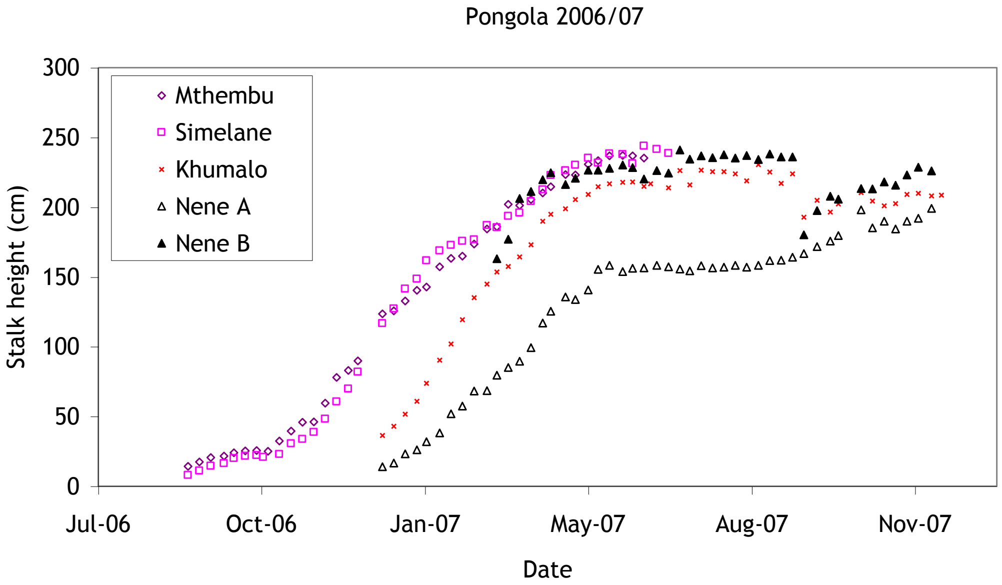


Figure 4.18 Measured stalk height for the 05/06 and 06/07 seasons at Pongola.

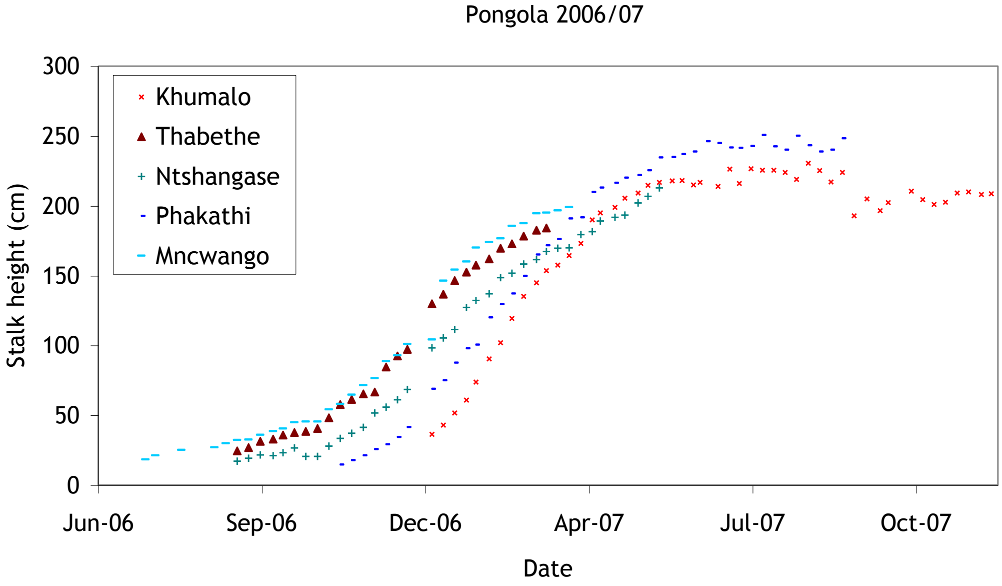


Figure 4.19 Measured stalk height for selected farmers for the 06/07 season at Pongola.

4.3.6. Advice validity

The validity of advice generated by the system and disseminated to farmers is summarised in Table 4.5. Incorrect advice was caused mainly by incorrect assumption about irrigation events due to slow or incorrect feedback from the fields. The most serious cases were incorrect advice to stop for Khumalo and Nene in both seasons and for Ntshangase, Mncwango and Phakathi in 2006/07. All of these were because farmers did not irrigate when advised to do so, while the system assumed that they were following advice. There was typically a two to three week lag in obtaining the information that farmers were not irrigating when they were advised to and this caused subsequent advice to be incorrect. Effort should therefore be made to reduce this lag time. This can best be accomplished by continuous, electronic monitoring of soil water content and daily automatic transmission of data to the ***MyCanesim*** server.

In most cases the percentage of incorrect advice was well below 10%, which is quite acceptable under the specific circumstances.

Table 4.5 Advice validity: The number of incorrect advice messages not to irrigate (stops) or to irrigate (starts) and percentage of advice that was incorrect for each farmer and season.

Season	Farmer	Incorrect stops	Incorrect starts	Incorrect advice (%)
2006/07	Mthembu D	5	8	4
	Simelane NM	3	11	4
	Thabethe BE	1	9	0
	Mncwango MT	17	6	7
	Ntshangase MA	10	1	3
	Phakathi FD	23	2	7
	Mbokazi A	8	10	5
	Khumalo NC	29	10	10
	Nene TZ	15	10	7
	Ave	12	7	5
2005/06	Nene TZ	11	12	6
	Mthembu D	1	14	5
	Simelane NM	42	2	11
	Khumalo NC	25	1	7
	Nene TZ	20	7	7
	Ave	5	8	4

4.3.7. Farmer adoption of advice

Adoption of advice is summarised in Table 4.6. Generally, unadvised stops are more common than unadvised irrigation. This was more prevalent in 2006/07 than in 2005/06 and is ascribed mainly to lack of water supply. It was particularly severe for Mncwango and Ntshangase as their electricity was cut off due to non-payment of accounts.

Table 4.7 shows the simulated impact of deviating from advice on yield and water use. The average irrigation shortfall in 2006/07 was a hefty 45% (due to inadequate water supply) resulting in an average yield shortfall of 27%. This is much higher than in 2005/06 (5 and 16% respectively). The lowest yield shortfalls were for Mthembu and Nene in both seasons, although Mthembu had a negative shortfall in irrigation in 2005/06 (i.e. over irrigation). Yield shortfalls in 2006/07 indicates a serious problem of profitability for farmers as it is this yield increment that often yields the profit for the farmer. It is therefore imperative for farmers to apply water when the crop needs it to ensure profitable cane production.

Table 4.6 The number of advised irrigation, actual irrigations, unnecessary irrigations and non-irrigations and the advice adherence index for each farmer and season.

Season	Farmer	# advised irrigations	# actual irrigations	Unnecessary irrigations	Unnecessary stops	Adherence Index(%)
2006/07	Mthembu D	18	20	3	0	83
	Simelane NM	22	14	0	8	64
	Thabethe BE	17	8	0	9	47
	Mncwango MT	17	5	3	9	29
	Ntshangase MA	24	8	1	15	33
	Phakathi FD	24	15	1	8	63
	Mbokazi A	24	12	0	12	50
	Khumalo NC	31	13	0	18	42
	Nene TZ	24	13	1	10	54
	Ave	22	12	1	10	52
2005/06	Mthembu D	20	28	5	0	75
	Simelane NM	26	14	1	11	54
	Khumalo NC	25	11	1	13	44
	Nene TZ	21	17	5	0	76
	Ave	23	18	3	6	62

Table 4.7 The simulated irrigation total from an ideal schedule and the resultant simulated yield for each farmer and season. The difference between the actual and the ideal amounts are expressed as percentage of the actual value.

Season	Farmer	Harvest date	Crop age (d)	Rain (mm)	Irrigation (mm)	Irrigation shortfall (%)	Cane yield (t/ha)	Yield shortfall (%)
2006/07	Mthembu D	22-Jun-07	359	801	798	15	121	21
	Simelane NM	6-Jul-07	354	810	966	43	114	25
	Thabethe BE	24-Mar-07	311	730	546	41	102	23
	Mncwango MT	10-Apr-07	334	738	588	75	109	36
	Ntshangase MA	29-May-07	374	790	798	77	125	43
	Phakathi FD	30-Sep-07	344	650	966	43	122	22
	Mbokazi A	25-Aug-07	361	703	840	36	128	31
	Khumalo NC	19-Dec-07	371	863	924	38	130	26
	Nene TZ	25-Dec-07	371	841	882	37	127	19
	Ave		353	770	812	45	120	27
2005/06	Mthembu D	26-Jun-06	392	511	1050	-33	119	6
	Simelane NM	1-Jul-06	322	495	1008	22	100	20
	Khumalo NC	7-Dec-06	387	685	1092	54	141	32
	Nene TZ	13-Nov-06	347	602	882	-6	121	7
	Ave		361	573	1008	5	120	16

4.4. Makhathini

4.4.1. Rainfall and irrigation input data

Due to the data collection problems reported previously, it was decided to use rainfall amounts measured by the Makhathini AWS, and irrigation amounts of 36 mm per recorded or assumed irrigation event, as simulation input. Irrigation events were assumed to occur once per cycle length for periods with no observed data.

Totals for irrigation water use and rainfall used in the simulation are compared with measured values in Table 4.8. The data show that the simulated totals for irrigation and rainfall are mostly higher than field recorded values. This is largely ascribed to large gaps in recorded data (see Table 4.8) and to suspect recordings.

The average irrigation depth per event that was measured was mostly reasonably close to the specification amount of 35 mm.

Table 4.8 Seasonal irrigation water use (IWU) totals (mm) as measured by gauges in the field and seasonal rainfall totals (mm) as recorded by the weather station (and used in the simulation) or measured by gauges in the field. The average depth (mm) of measured irrigation events and the number of days with missing field data are also given.

Season	**Farmer**	**IWU**			**Rainfall**		**Missing Data (d)**
		My Canesim	Field rain gauge	Depth	***My Canesim***	Measured	
2006/07	Mathenjwa	489	477	40	580	692	0
	Gumbi	789	317*	52	603	582*	217
2005/06	Mathenjwa field A	592	335	42	840	481	130
	Mathenjwa field B	592	345*	43	792	285*	156
	Zondo	361	292*	36	399	365*	63
	Ngxongo	768	643	49	895	331	86
	Myeni	335	300	33	684	686	37

* Incomplete: The growing season was only partially monitored

4.4.2. Simulation accuracy: Soil water balance

Measured and simulated values of the water balance for five fields for 2005/06 season are shown in Fig. 4.20 to 4.24.

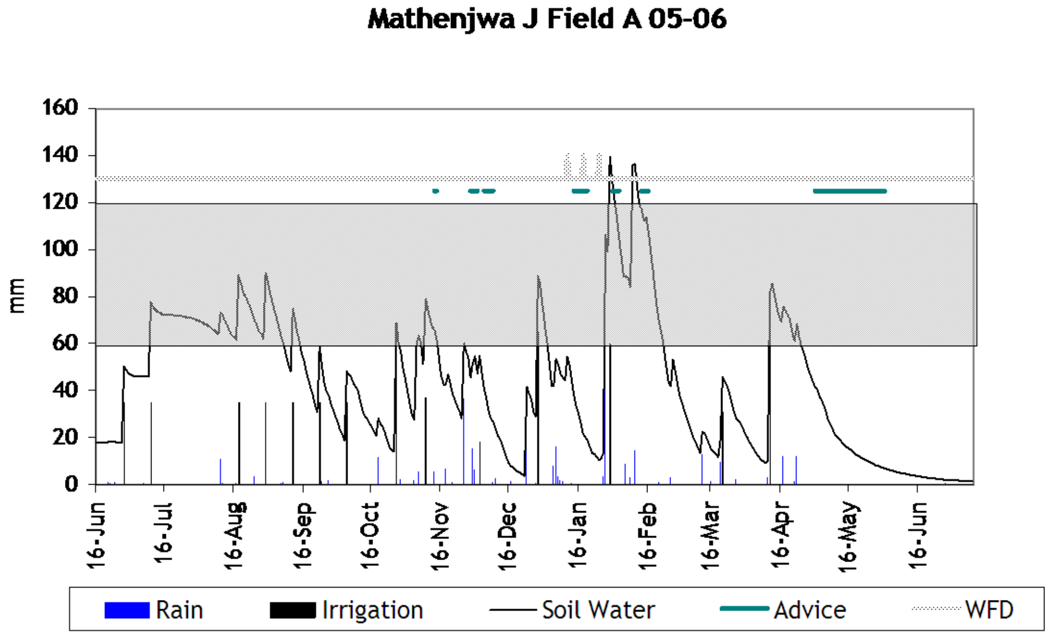
The main points of interest are:

Mathenjwa fields A and B: There is a mid-season drop of simulated soil water outside the target range partly due to high demand and partly due to short periods of no water supply. Some of the advice to stop irrigation during this period was based on incorrect weather data at the time. This problem has been rectified. The drop in ASW at the end of the season was due to drying-off advice based on an assumed harvest date, which was then delayed for several weeks without prior notice. WFD recordings confirm the simulated ASW trends.

Zondo BM: The simulated ASW barely remained in the target range for the first half of the season due to the long irrigation cycle. In the second half of the season, irrigation was suspended completely because short sprinklers were used that could not distribute water adequately in the tall cane. WFD recordings confirm the simulated ASW trends.

Nxgongo: A similar pattern to that of Zondo emerged. The first half of the season is characterised by frequent irrigation and adequate soil water status. Irrigation pipes were removed in February and the field received no further irrigation, also because of the difficulty using short sprinklers in tall cane. Other problems encountered here were the termination of the field assistant's (the recipient of advice) tenure, mid-way through the season and the absence and non-participation of the owner in project activities. There was no significant opportunities and advice to save water.

Myeni D: The long irrigation cycle (12 days) caused frequent periods of water stress throughout the season. There were also long periods (Mar to Jul) where the farmer stopped irrigation against the advice. The farmer stated that waterlogging was the reason and an investigation confirmed waterlogged conditions in low-lying areas of the field where monitoring occurred. WFD observations seem to confirm this. However large parts of the field in higher lying areas were clearly dry and water stressed. A second monitoring site in a higher lying part of the field was established in January 2007 to better understand spatial variation in the field. Short sprinklers must have contributed to the unwillingness to irrigate tall cane. There was little opportunity to save irrigation water. The advice sent in September to stop irrigation was based on incorrect assumptions for irrigation practices at the time. This probably led to an excessively long drying off period, which could have had a negative impact on yield. This emphasises the importance of timely feedback about past irrigation schedules to the ***MyCanesim*** system.



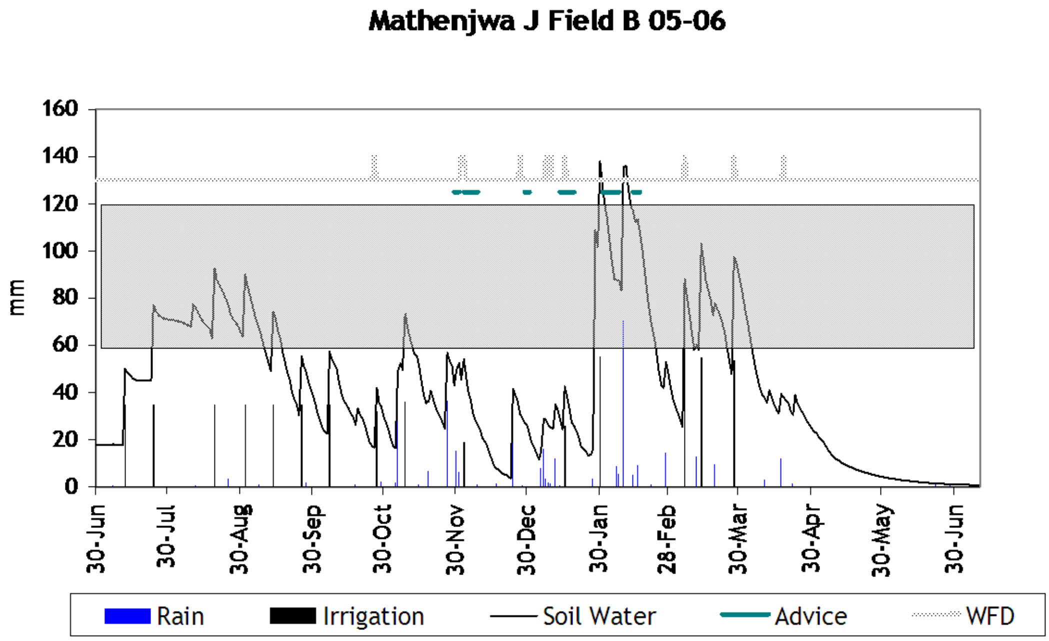
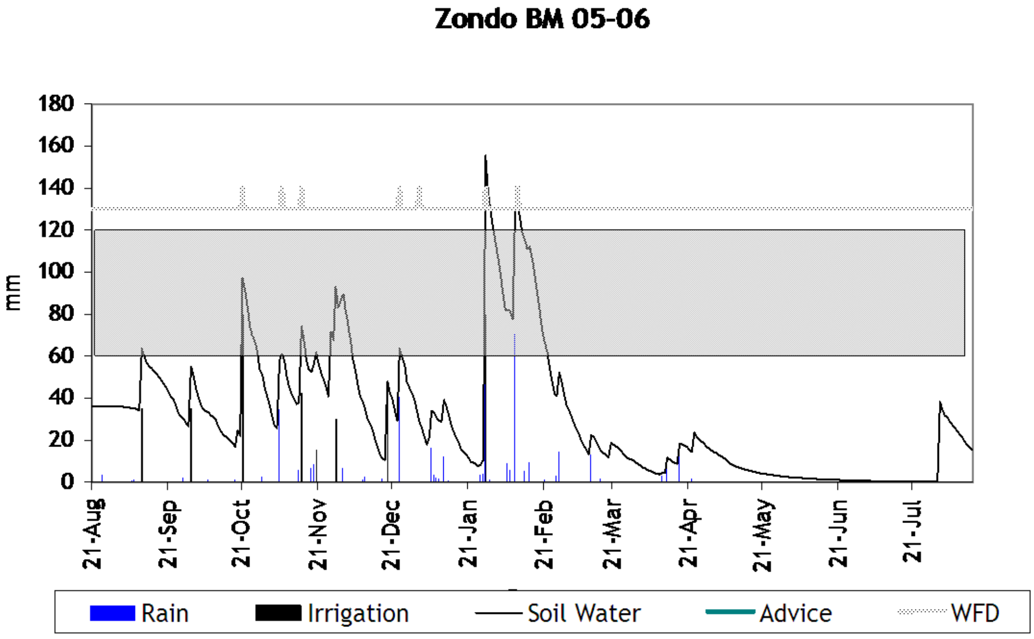


Figure 4.20 The simulated water balance for Mathenjwa (2 fields) for the 05/06 season. The figure shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.



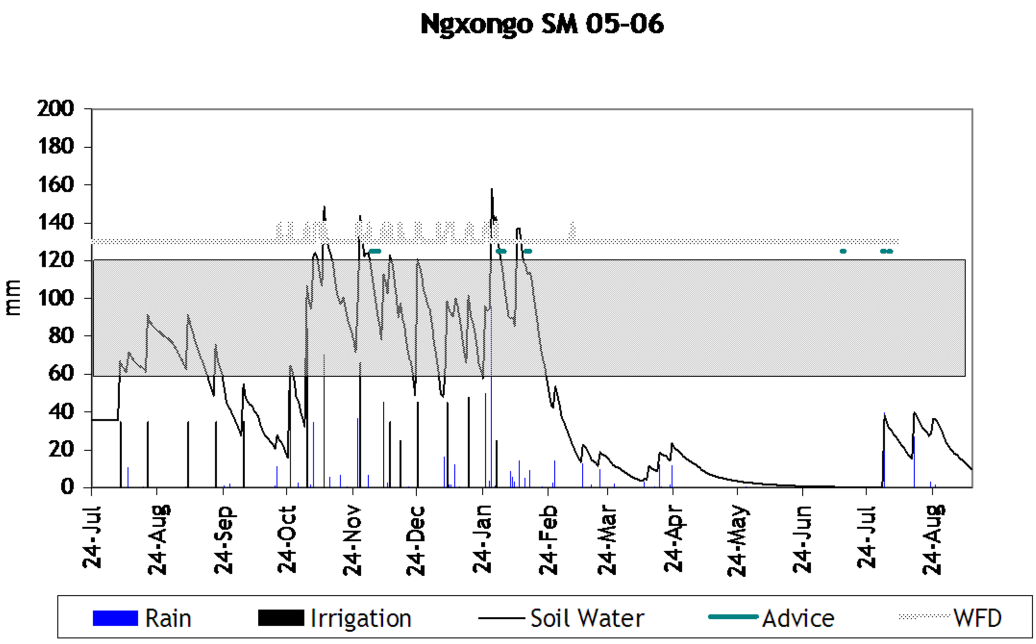


Figure 4.21 The simulated water balance for farmers Zondo and Nxgongo for the 05/06 season. The figure shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

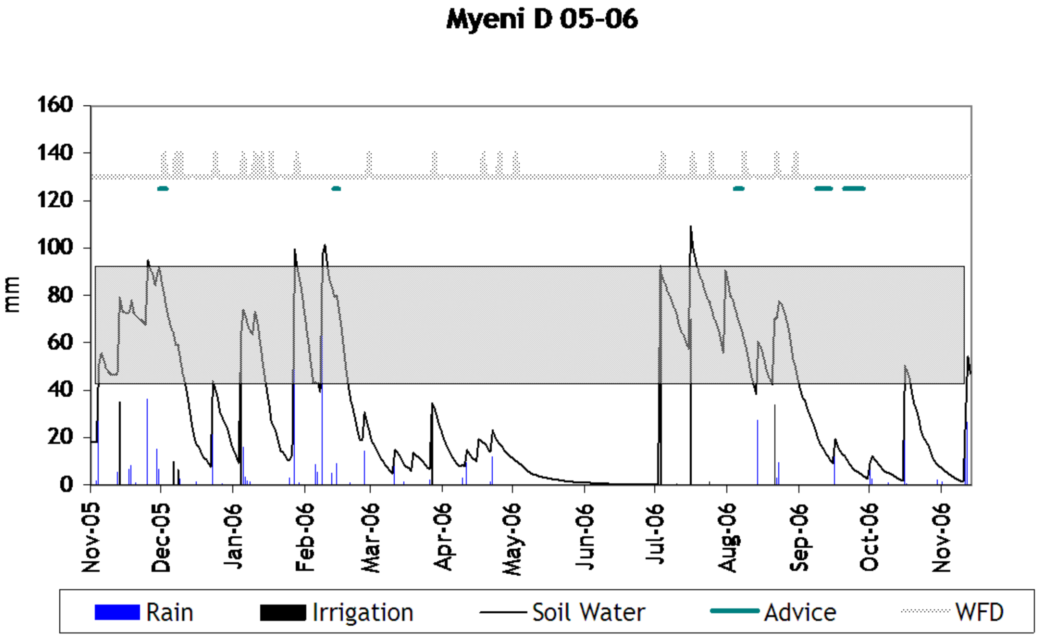


Figure 4.22 The simulated water balance for Myeni for the 05/06 season. The figure shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line) and whether wetting front detectors (WFD, topmost light line) indicated a wetting front depth of at least 50 cm or not.

Monitoring on the fields of Zondo and Nxgongo was terminated after the harvest of the 2005/06 crop because they did not fulfil the minimum requirements for monitor participants. Although Gumbi was selected to participate as monitor participant, this only occurred in October 2006, while his crop had already started in March 2006. Furthermore, data collection was terminated on all fields in June 2007. Therefore, the only meaningful evaluation that was possible for the 2006/07 season was for the field of Mathenjwa (Fig. 4.23).

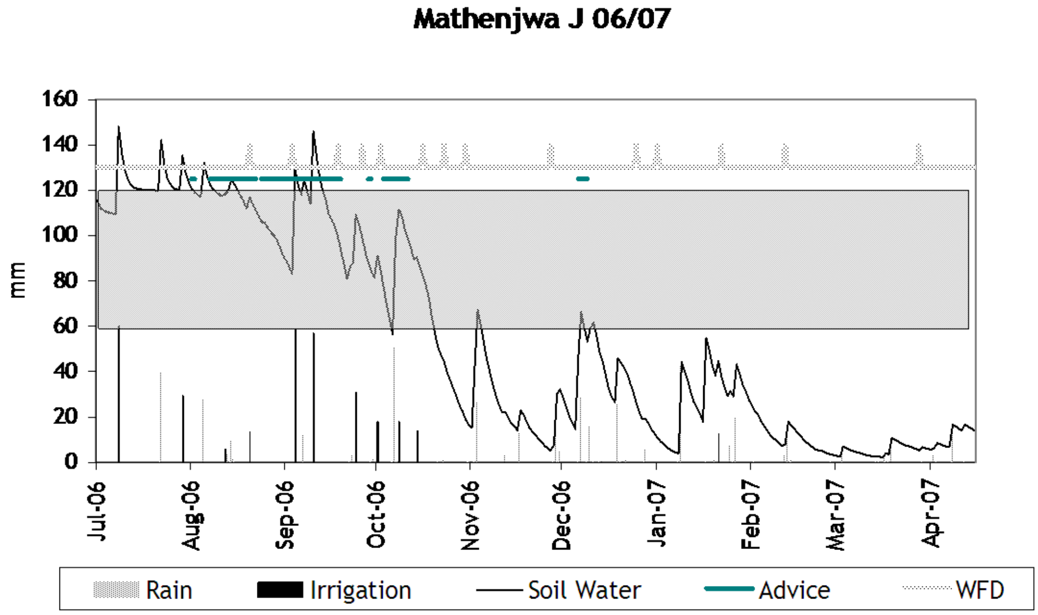
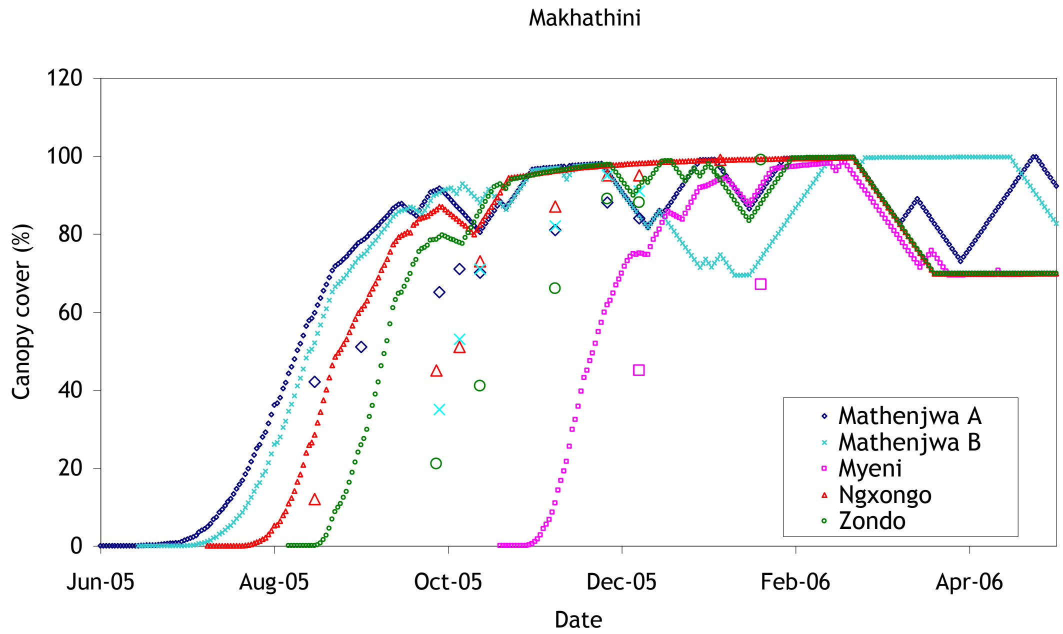


Figure 4.23 The simulated water balance for farmer Mathenjwa for the 06/07 season. The figure shows daily rainfall (solid blue bars) and irrigation (solid dark bars) amounts, simulated available soil water (ASW, bold solid line) and the target ASW range (grey block). It also shows when the advice was to NOT irrigate (second from top, solid horizontal line) and whether none (no blip), one (half a blip) or both (full blip) wetting front detectors (WFD, topmost light line) indicated a wetting depth of at least 50 cm.

Simulation and observations show that soil water content reached saturation in August 2006 and remained high for about a month. During this period the farmer received advice to stop, which he did not adhere to. From November 2006 to January 2007, the model simulated suboptimal soil water content. WFD observations sometimes contradicted this. We believe that this is due the poor quality of field recordings of irrigation used as input in simulations.

4.4.3. Simulation accuracy: Canopy cover

Simulated and measured canopy cover is shown in Fig 4.24.



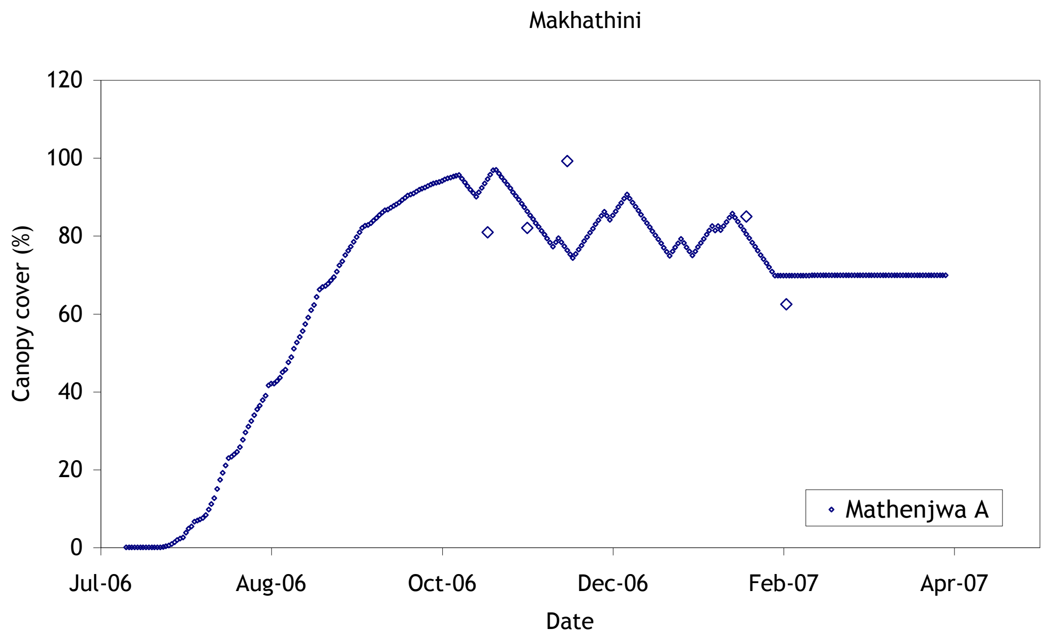


Figure 4.24 Simulated (lines) and measured (markers) canopy cover for the 05/06 (top) and 06/07 (bottom) seasons in Makhathini.

The model overestimated early canopy development in most cases. This could possibly be due to poor growth because of suboptimal water status, or to possible unique features of the temperature regime experienced in Makhathini. Further investigation is required. The impact of stress on the mature canopy seems to be realistically simulated, as indicated by the good comparison between simulated and observed values later in the growing season.

4.4.4. Simulation accuracy: Yield

Final simulated and measured values of yield, crop growth and water use for 05/06 are given in Table 4.9. Simulated yields were generally well below yields sampled in the field. This is ascribed to the poor quality of the irrigation and rainfall input data. Measured stalk lengths were quite acceptable and associated with high yielding crops for all cases that were measured except for Myeni. Measured stalk populations were quite high except for Ngxongo.

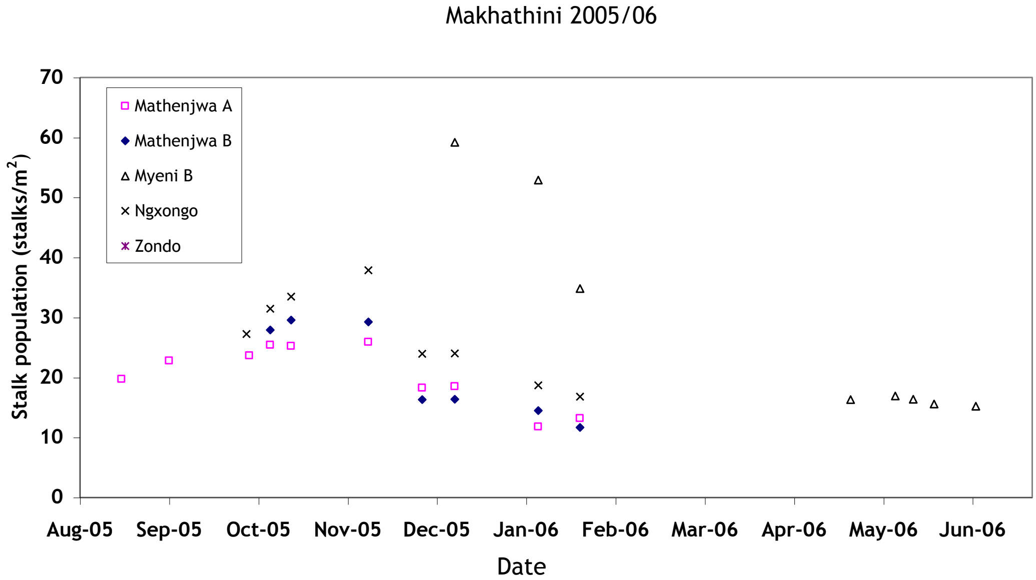
Table 4.9 Simulated yields compared to yields estimated from a field sample. Measured stalk length and population at harvest are also given.

		Cane yield (t/ha)		Stalk	
Season	**Farmer**	***My Canesim***	**Field Sampled**	**Length (cm)**	**Pop ($/m^2$)**
2005/06	Mathenjwa field A	83	NA	NA	NA
	Mathenjwa field B	82	NA	NA	NA
	Zondo	65	153	233	17.4
	Ngxongo	91	118	273	9.5
	Myeni	72	119	200	21.6
2006/07	Mathenjwa	48	102	240	16

NA – Not available

4.4.5. Observed crop growth

Measured stalk population and height for the 2005/06 and 2006/07 seasons are shown in Fig. 4.25 and 4.26. The data shows poor growth for Myeni (short stalks) and Nxgongo (low stalk population).



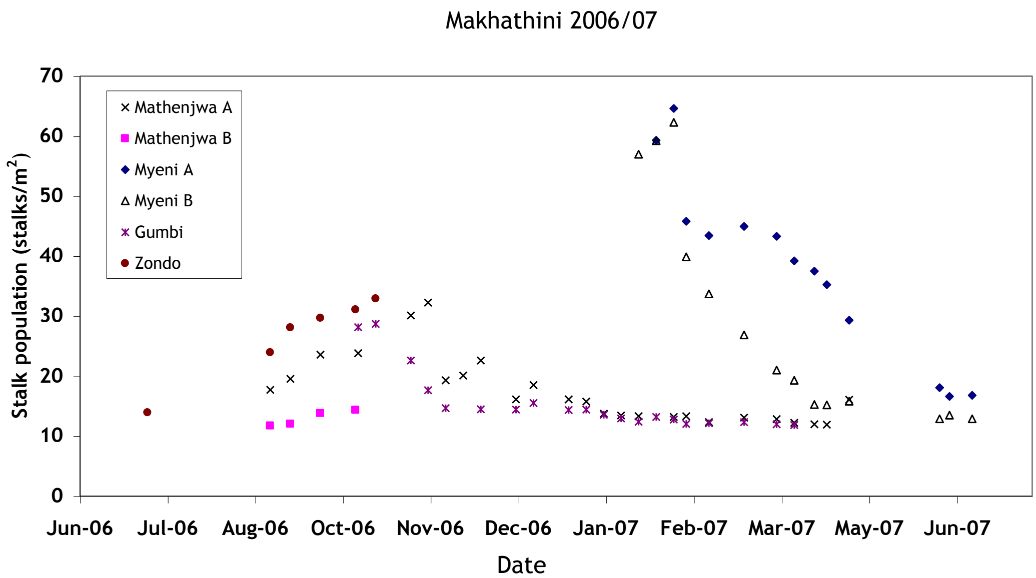


Figure 4.25 Measured stalk population for the 05/06 and 06/07 seasons at Makhathini.

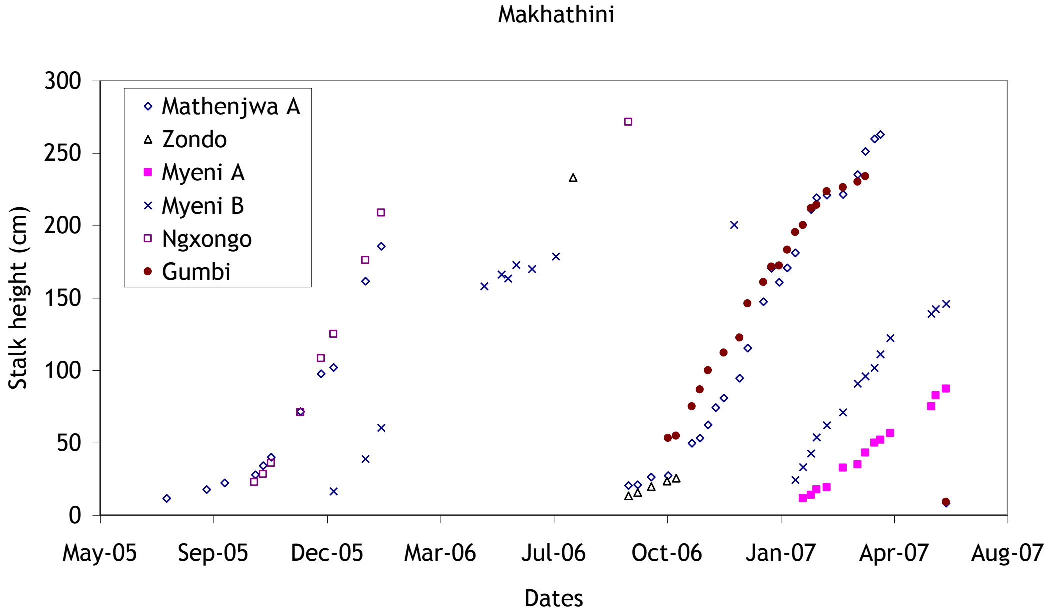


Figure 4.26 Measured stalk height for the 05/06 and 06/07 seasons at Makhathini.

4.4.6. Adoption of advice

The system seldom advised farmers to stop irrigating due to the inability of irrigation systems to keep up with evaporative demand (see Fig. 4.20 to 4.23). Furthermore, in the few isolated cases that it did happen, it was mostly incorrect due to invalid assumptions regarding irrigation practices. Farmers often did not irrigate (apparent from recordings) when the system advised them to do so. The main reason was the cessation of irrigation after the cane canopy extended above irrigation sprinklers (see Fig. 4.20 to 4.23).

It is estimated that the non-adherence to advice had a profound effect on irrigation water use and yields. It is estimated that on average, farmers could and should have applied approximately 85% more water than they had, even with the long irrigation cycles of existing systems. This irrigation shortfall caused an estimated yield shortfall of 60%, on average. The estimated irrigation and yield shortfalls are even larger when benchmarked against ideal irrigation schedules with the specification cycle of 7 days (see Table 4.10).

Table 4.10 The simulated irrigation total from an ideal schedule with the current irrigation cycle (and with the specification cycle of 7 days in brackets) and the resultant simulated yield for each farmer and season. The difference between the actual and the ideal amounts are expressed as percentage of the actual value.

Season	Farmer	Harvest date	Crop age	Rain (mm)	Irrigation (mm)	Irrigation Shortfall (%)	Cane yield (t/ha)	Yield Shortfall (%)
2006/07	Mathenjwa	2006/4/26	281	580	735 (1015)	50 (107)	94 (116)	80 (121)
2005/06	Mathenjwa field A	2006/06/10	389	576	1015 (1330)	71 (125)	121 (142)	45 (69)
	Mathenjwa field B	2006/06/10	375	577	1015 (1295)	71 (118)	119 (138)	45 (68)
	Zondo	2006/08/14	358	597	595 (1260)	65 (250)	95 (137)	46 (110)
	Ngxongo	2006/09/11	414	652	1015 (1400)	32 (82)	135 (156)	47 (71)
	Myeni	2006/12/08	401	769	1085 (1470)	223 (338)	139 (161)	93 (123)

4.5. Conclusions

In Pongola, observations of canopy cover, soil water status and cane yield in four fields in 2005/06, and in nine fields in 2006/07, show that model simulations of these variables were reasonably accurate when the Canesim model was supplied with accurate input data. Simulated canopy cover and yield compared well with observed values. Wetting front detector responses suggest that the Canesim model sometimes under-estimated soil water status and it is recommended that this problem be further investigated with a view to improve the model.

For Pongola, the spatial variation in rainfall was low and rainfall data recorded by a single automatic weather station was sufficient for accurate simulations. The study showed the importance of accurate irrigation data input. It proved quite difficult to obtain timeous and reliable irrigation data from farmers. Assumptions that farmers followed advice to irrigate or not were not always correct and this led to incorrect simulations and advice about 5% of the time. The main reason for farmers not following advice was lack of water supply when advised to irrigate. The causes of this were electricity cuts due to non-payment, pump breakdowns and interruptions in water supply at scheme level.

Implementation at Makhathini was problematic. Five fields were monitored in 2005/06 and this decreased to only two fields in 2006/07 that fulfilled the criteria for monitor participants. The main problem was inadequate irrigation systems that result in excessively long irrigation cycles that exceed the design specifications by two or threefold. In practice, this amounts to supplementary irrigation. Irrigation was often also stopped entirely midway through the growing season because sprinkler stands were too short to distribute water above the cane canopy.

Furthermore, it was very difficult to obtain reliable irrigation and rainfall data during the 1st season because it was difficult to make farmers understand the trial objectives and methods. The integrity of yield data at a scheme level was questionable, while no water use data was available. It was further impossible to obtain harvest schedules in advance. This made effective research and service provision impossible and field monitoring was terminated in May 2007. Weather data collection and processing continue, while irrigation advice is still being provided to all farmers that subscribed initially.

Most Makhathini farmers were unable to benefit from the advice because the irrigation systems are inadequate to supply the required amount of water. It is estimated that on average, farmers could and should have applied approximately 85% more water, even with the long irrigation cycles of existing systems. This caused an estimated yield shortfall of 60%. Despite numerous attempts to convince participants to upgrade and repair irrigation systems and to improve crop husbandry, nothing has changed. Lack of land ownership, lack of cash flow and a 12-hour per day water supply are severe limitations to correcting these problems.

5. EVALUATION AT SCHEME LEVEL

5.1. Introduction

Assessing water use and yield achieved by all farmers on the Pongola scheme could provide insight into the impact of irrigation advice and associated extension. Trends over three seasons and comparisons between the performance of subscribers to the advisory service and that of non-subscribers could shed light on the impact of the service on cane yield, irrigation water use and irrigation water use efficiency (defined as the fresh cane yield divided by seasonal irrigation applied in units of kg/m^3).

Fresh cane yield (CY) was determined for all fields with good mill delivery data. Seasonal irrigation applied (named irrigation water use, IWU) was estimated for all fields with good flow meter data (supplied by Impala Water Users' Association). Average CY and IWU were calculated for three groups of farmers namely, (1) monitor participants (farmers whose field were monitored and which had good CY and IWU data – 5 in 2004/05, 4 in 2005/06 and 8 in 2006/07), (2) advice participants (subscribers to the advisory service whose fields were not monitored but had good CY and IWU data – none in 2004/05, 26 in 2005/06 and 25 in 2006/07), and (3) non-participants with good CY and IWU data (33 in 2004/05, 11 in 2005/06 and 3 in 2006/07).

5.2. Results and discussion

IWU, CY and irrigation water use efficiency (IWUE) results for all farmers with good data are given in Table 5.1. Average values for the different groups of farmers are shown in Table 5.2.

Table 5.1 Irrigation water use (IWU), cane yield and irrigation water use efficiency for different farmers, based on mill delivery and flow meter data respectively. The type of project participation is also given: 1 – Monitor participants, 2 – advice participants and 3 – non-participants.

	2005/06				2006/07			
Farmer name	**IWU (mm)**	**Cane yield (t/ha)**	**IWUE (kg/m3)**	**Part**	**IWU (mm)**	**Cane yield (t/ha)**	**IWUE (kg/m3)**	**Part**
Dhlamini MJ	654	74	11	3	641	66	10	3
Dlamini LZ	551	79	14	2	400	78	20	2
Dlamini MM	728	72	10	3	NA	NA	NA	3
Dube Z	614	94	15	2	145	62	43	2
KhanyeTT	1095	96	9	2	545	95	17	2
Khumalo MH	743	84	11	2	553	82	15	2
Khumalo NC	753	91	12	1	279	83	30	1
Magagula ST	820	76	9	3	316	64	20	3
Magagula VS	380	72	19	2	145	38	26	2
Malinga ME	645	68	11	3	663	65	10	2
Malinga RT	820	93	11	2	454	83	18	2
Mamba SE	990	39	4	2	138	25	18	2
Mamba SS	864	91	11	3	531	77	15	2
Mathe CE	1477	97	7	2	646	87	13	2
Mbokazi NA	1327	129	10	2	925	116	13	1
Mbuyisa VO	749	119	16	2	180	87	48	2
Mncwango MT	1294	98	8	2	513	81	16	1
Mthembu D	1203	126	10	1	1126	112	10	1
Mtshali TM	674	66	10	3	135	22	16	2
Ndwandwe MM	752	82	11	2	NA	19	NA	2
NeneTZ	753	80	11	1	652	NA	NA	1
Ngwenya MK	688	51	7	2	NA	NA	NA	2
Nhleko ZA	714	102	14	2	381	67	18	2
Nkambule KO	1175	101	9	2	1091	96	9	2
Nkosi BJ	602	79	13	3	498	74	15	2
Ntshangase GJ	497	65	13	2	NA	44	NA	2
Ntshangase LD	774	80	10	2	518	57	11	2
Ntshangase MA	856	73	9	2	309	74	24	2
Nxumalo ZL	767	71	9	2	141	43	31	2
Nyawo BL	727	72	10	2	224	67	30	2
Nyembe MZ	386	97	25	2	201	67	33	2
Phakathi FD	855	94	11	2	670	89	13	1
Shabangu NE	1037	73	7	3	1215	46	4	3
Sibiya CE	434	103	24	3	238	90	38	3
Simelane NM	823	72	9	1	876	73	8	1
Siyaya B	388	107	28	2	762	106	14	2
Thabede DA	590	62	11	2	NA	NA	NA	2
Thabede MA	913	92	10	2	623	68	11	2
Thabethe BE	517	146	28	2	557	82	15	1
Xaba GS	744	66	9	3	591	55	9	2
Zungu MP	727	100	14	2	930	14	2	2

NA – Reliable data not available

Table 5.2 Cane yield, seasonal irrigation water use and irrigation water use efficiency for different groups of farmers for three seasons. The number of farmers that make up each group are shown in brackets.

Season:	**2004/05**	**2005/06**	**2006/07**
Cane yield (t/ha)			
All farmers with data	107 (38)	86 (41)	70 (36)
Monitor participants	107 (5)	92 (4)	92 (8)
Advice participants	NA	90 (26)	67 (25)
Non-participants	92 (33)	83 (11)	62 (3)
Irrigation water use (mm)			
All farmers with data	910	783	520
Monitor participants	974	883	700
Advice participants	.	823	450
Non-participants	901	720	NA.
Irrigation water use efficiency (kg/m3)			
All farmers with data	11.02	11.64	16.81
Monitor participants	11.00	11.18	12.40
Advice participants	NA.	11.00	19.50
Non-participants	11.30	10.10	NA.

NA – reliable data not available

The scheme average CY and IWU declined over time, while IWUE increased. This ascribed to a declining water supply due to increased down time of infrastructure at the scheme (50 days in 2006/07 compared to 21 days in 2005/06) and at the field level (increased incidence of pump breakdowns and electricity cuts over time). The method of paying for irrigation water and its application was also changed (see section 3.2), with farmers becoming individually responsible for payment of electricity to operate infield pumps. This created an incentive for using less water and in some cases non-payment led to electricity cuts with resultant cessation of irrigation. In summary, factors outside the scope of this study unfortunately played a dominant role in the long-term trends in water use and cane yield observed on the Pongola scheme.

For monitor participants, average yield and water use for the 2005/06 and 2006/07 seasons were higher (92 t/ha and 791 mm compared to 78t/ha and 637 mm), and the decrease in yields and water use from 2005/06 to 2006/07 was much less (0 t/ha and 183 mm compared to 23 t/ha and 373 mm), than for advice participants. This could possibly be ascribed to the more frequent and intense interaction of My Canesim representatives with farmers that led to more appropriate irrigation scheduling. In the 2005/06 season, average yield and water use of advice participants were higher than for non-participants (90 compared to 83 t/ha and 823 mm compared to 720 mm, respectively). This seems to confirm the aforementioned conclusion.

It may also be insightful to evaluate trends over three seasons in CY, IWU and IWUE for those farmers that were monitor participants in 2006/07. The average IWU for this group declined from 950 mm in 2004/05 to 941 and 699 mm in the next two seasons. Average yields were 99.4, 104.3 and 90.9 t/ha. IWUE increased from 11.0 kg/m^3 in 12004/05 to 12.3 and 14.9 kg/m^3 in the following two seasons.

It should be noted that IWUE data needs to be interpreted with caution. Large increases in IWUE often are associated with very low (suboptimal) IWU similar to a "supplementary irrigation scenario". For example Olivier and Singels (2003) found a range from 13 to 24 kg/m^3 depending on the amount of irrigation applied. The cane plant is able to still produce a yield using rainfall, which then results in very high IWUE values. IWUE can only be interpreted meaningfully in the context of its underlying components namely CY and IWU. Economically the farmer must achieve break-even yield to cover overhead costs and yields below 90 t/ha are unsustainable from a business point of view. For yields exceeding this point the concept of IWUE could possibly be used to quantify efficiency of irrigation water use. IWUE values of more than 10 kg/m^3 can then be regarded as acceptable.

5.3. Conclusion

Factors outside the scope of this study unfortunately played a dominant role in the long-term trends in water use and cane yield observed on the Pongola scheme. Declining water availability, changed method of payment for water and lack of infrastructure maintenance contributed to a general decline in irrigation water use and yield. However subscribers to the service experienced lower rates of decline and applied more water and achieved higher yields than non-subscribers. This suggests that the advisory service had a beneficial impact on the productivity and profitability of irrigated small-scale sugarcane production.

6. FARMER SURVEY

6.1. Introduction

A survey was conducted amongst Pongola farmers to assess (1) perceptions concerning the quality of the service and (2) the impact it has on farmer capacity, farming operations and profitability. This will assist in deciding whether the service should be continued and, if so, to help formulate an appropriate business model. It will also point out aspects that require possible improvement.

6.2. Method

It was decided to conduct the survey by face-to-face interviews with farmers. A draft questionnaire was developed to address the issues highlighted in Table 6.1. The approach was to use multiple-choice and simple language to accommodate quick translation into isiZulu. After a test on five farmers, misunderstood questions were rephrased and several redundant or cumbersome questions were eliminated in order to shorten the excessively long interview time (2 hours). Questions that were intentionally skipped during interviews are shown as strikethrough text in the questionnaire shown in Appendix 11.5.

Twenty farmers were interviewed from December 2006 to March 2007. One-on-one Interviews were conducted by Dumisile Mthembu, a daughter of farmer Mthembu and known to most of the interviewees. This may have had an influence on the forthrightness of responses.

Table 6.1 Criteria, keywords and key questions for the farmer survey.

Criteria		The keywords and key questions
Format	Content	Amount of information (too much / too little) Is all the advice useful?
	Design	Is the translation in Zulu in the text message correct? Do they like the style and design of the advice? Their preference of frequency of the advice (daily, weekly, bi-weekly, monthly, bi-monthly) Other communication means, what type? Other type of advice delivery (phone, fax)
Adoption / acceptance		Do you agree with the advice? Reasons for not following the advice. When you are unable to irrigate, do you send a reply SMS (always, sometimes or never). Why?
Reliability		Do farmers trust this advice? Timing of the advice and extension follow up How accurate was the input parameter of the '***MyCanesim***' system?
Relevance		Comparison between: The state of soil and the advice The state and requirements of the plant and the advice The weather and the advice (rain = stop) The practicality of the advice given the irrigation system. *Is the advice suitable for the irrigation system? (Number of sprinklers; irrigation cycle)*
Impact	Agronomy and environment	Growth of the crop (Yield before /after advice) Impact of the advice on fertilisation (quantity, result) Quantity of water used? (Before and after)
	Economy	How much are they prepared to pay for this service? How much did this advice reduce the cost of irrigation?
	Labour	How long after the advice do they respond? How long does it take to move sprinklers?
Capacity building		What have you learnt about irrigating sugarcane from this service, especially with regard to: - the need to schedule irrigation - the need to adapt the water use to the season and / or the weather - the need to respect the irrigation cycle. - the importance of a knowledge of agronomic parameters of the field (soil, variety, date of start and harvest) - the capacity to manage the irrigation alone?

6.3. Results

Results are illustrated in Fig. 6.1 to 6.3. The data shown in these figures should be interpreted as follows: Each question has several possible responses represented by numbers (indicated in brackets following the question). Possibilities vary between questions. The lowest and highest numbers chosen by farmers are shown as the left and right end respectively on the horizontal bar, while the average response is indicated as a separator inside the body of the bar.

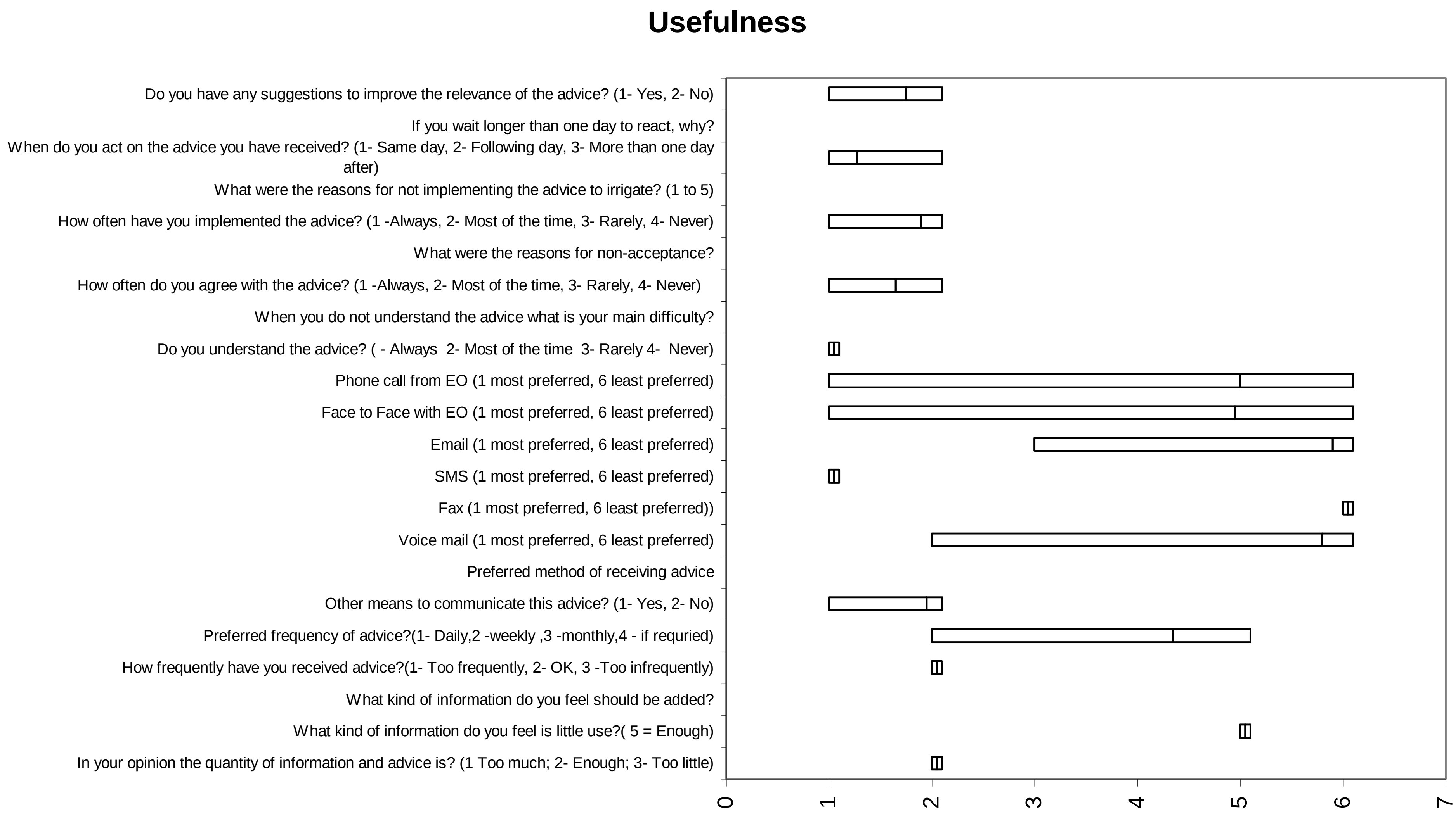


Figure 6.1 Farmers' responses (minimum, average and maximum value) to survey questions regarding the usefulness of the service.

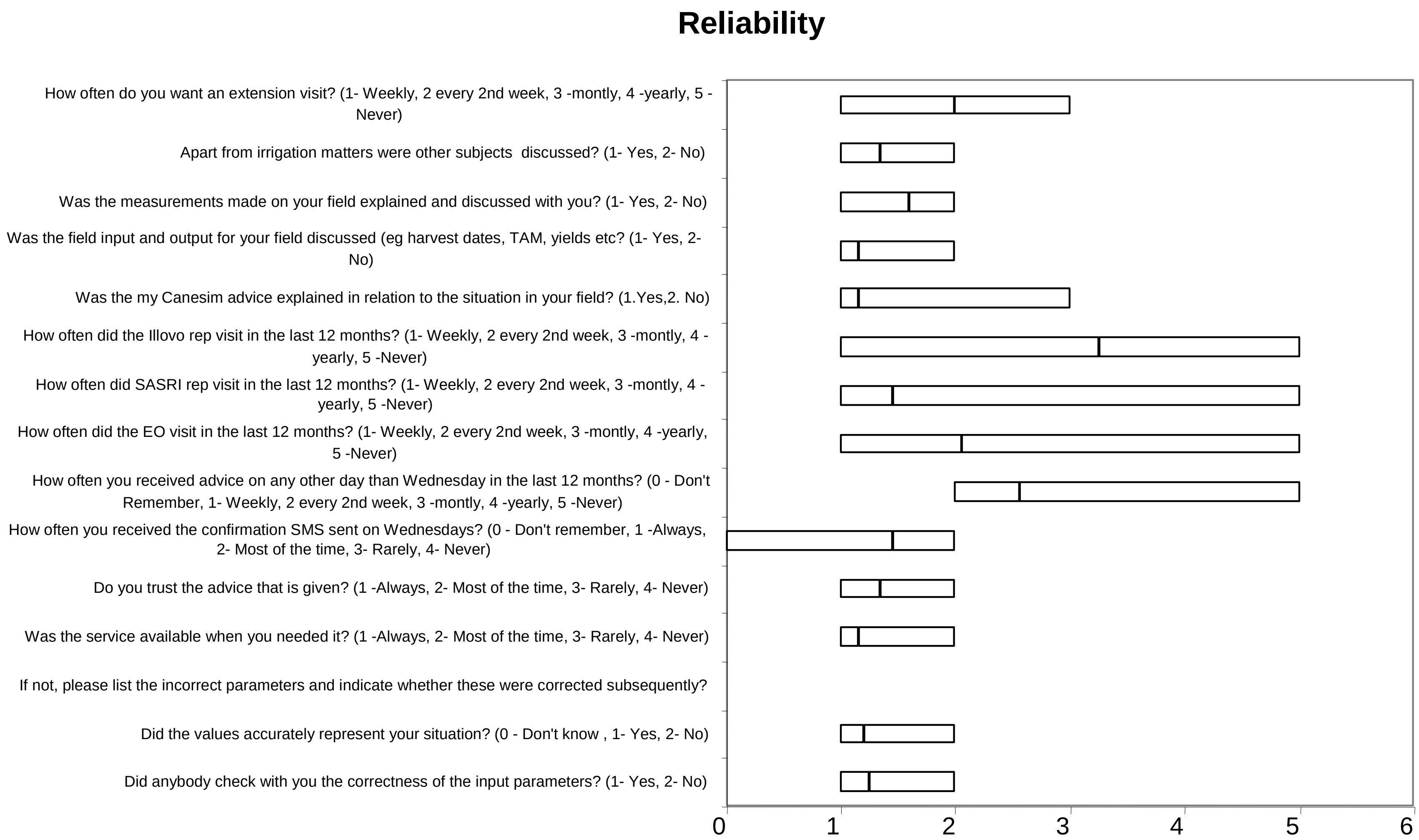


Figure 6.2 Farmers' responses (minimum, average and maximum value) to survey questions regarding the reliability of the service.

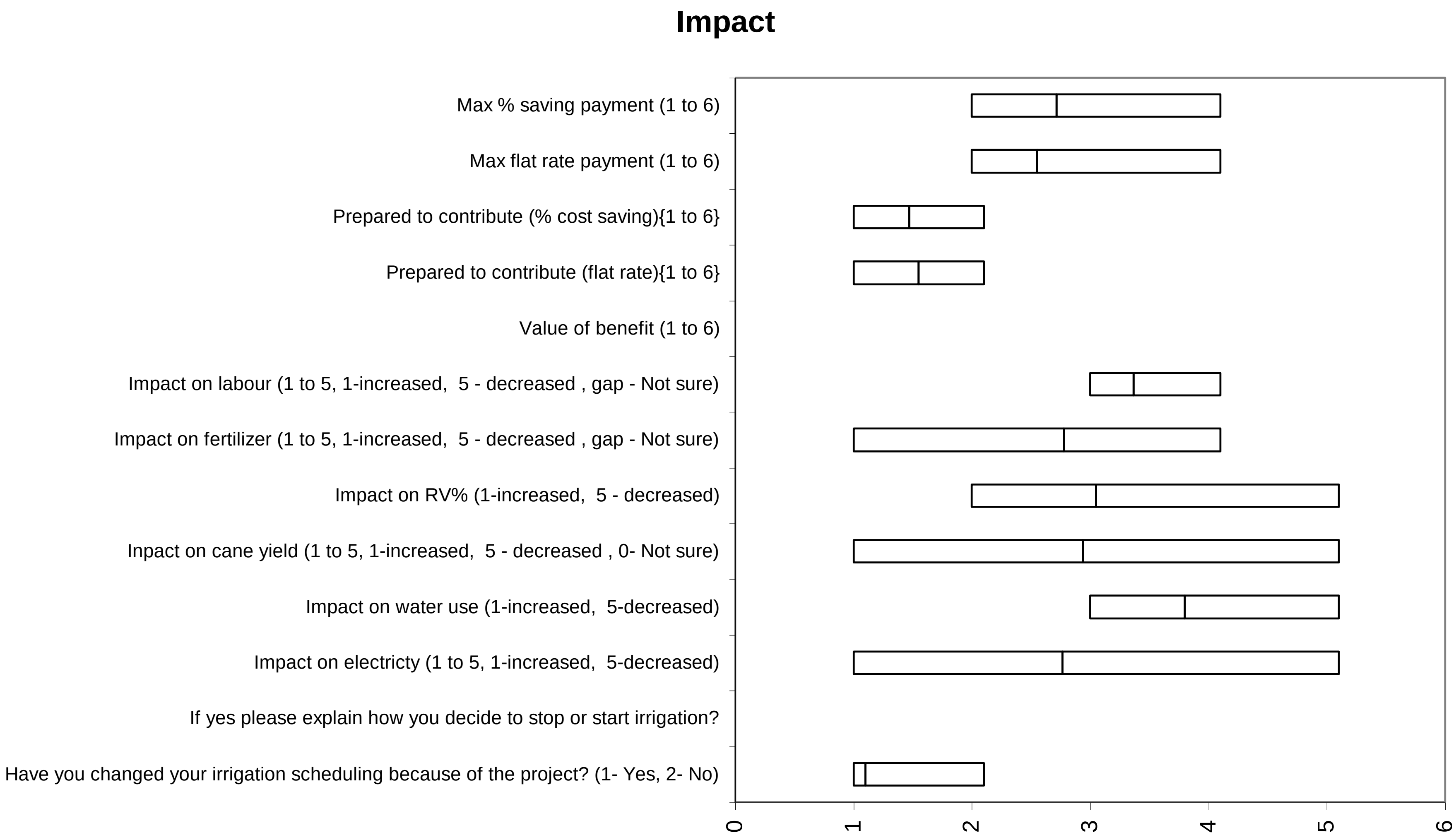


Figure 6.3 Farmers' responses (minimum, average and maximum value) to survey questions regarding the impact of the service.

In summary the main findings from the survey were:

- All farmers thought that the amount, frequency and delivery mode of advice was most appropriate and preferred not to have it changed.
- Farmers found advice useful (20/20), easy to understand (20/20), agreed with it most (12/20) or all of the time (8/20), trusted it most (7/20) or all of the time (13/20) and implemented it most (17/20) or all of the time (3/20), within one (15/20) or two (5/20) days after receiving it.
- Farmers were visited by SASRI technicians, the Illovo representative or the KZNDA extension officer every week (16/20, 5/20 and 9/20 respectively) or once or twice a month (3/20, 6/20 and 9/20 respectively). A few farmers have never been visited (1/20, 8/20 and 2/20 respectively).
- Correctness of field inputs was not verified with farmers in 5/20 cases and in 4/20 cases was subsequently found to be incorrect. The input data for other farmers were verified by technicians and were found to be correct.
- Farmers became more aware of the importance of irrigation scheduling in increasing revenue and reducing costs (20/20).
- Most farmers changed irrigation scheduling because of the advice (19/20) and believed that irrigation water use decreased (5/8) or remained the same (3/8).
- The perceived impact on cane yield varied from slightly increased (4/9) to slightly decreased (3/9). The remainder (11/20) were not sure about the impact.
- Sixteen farmers were prepared to pay a small service fee (8/20 – less than R10/ha; 8/20 – between R10 and R50/ha).

6.4. Conclusions

In conclusion, the survey showed that most Pongola farmers found the irrigation advice useful and easy to understand, and trusted the advice most of time. The project made farmers more aware of the importance of irrigation scheduling in increasing revenue and reducing costs, and most farmers have changed irrigation practices because of the advice. The majority of farmers indicated that they wanted the service to continue and are prepared to pay a small service fee.

7. FEASIBILITY OF IMPLEMENTING AN OPERATIONAL IRRIGATION ADVISORY SERVICE

7.1. Introduction

The goal was to determine the financial feasibility of providing an operational irrigation scheduling advice service to commercial and small-scale sugarcane farmers in South Africa. A technical report by Fourie and Grové (2008) fully describes the study conducted in this regard and is included in Appendix 11.6. A summary of this work is presented below together with a follow up analysis using different assumptions but the same methodology established by Fourie and Grové (2008).

The specific objectives of the study were to (1) quantify the potential impact of an advisory service on cane yield and irrigation water use and the subsequent monetary benefit to farmers, and (2) budget the cost of two service implementation options and calculate the unit cost and net benefit to farmers for three subscription scenarios.

7.2. Method

The method of calculating the net benefit of service provision to farmers consisted of the following steps:

1. Determine the impact of irrigation advice on irrigation water use and cane yield using various sets of assumptions.
2. Determine the monetary gain (increase in gross margin above specified costs) achieved by farmers that can be attributed to the advice.
3. Determine the cost of service provision for different implementation options and subscription scenarios.
4. Calculate the net benefit of service subscription by deducting the cost of service provision from the net monetary gain attributable to the service.

7.2.1. Service impact assumptions used by Fourie and Grové (2008)

The IWU and CY data obtained in this study for the Pongola scheme was deemed unsuitable for estimating the impact of irrigation scheduling advice, because of the strong influence of factors such as limited water supply and because the data was unbalanced. Instead, the ***MyCanesim*** system was used to simulate water use and yields for Pongola for two irrigation strategies namely (1) a variable strategy of applying 42 mm every 10 days when the soil water deficit approached 50% of the available soil water capacity, and (2) a fixed strategy of applying 42 mm every 10 days regardless of soil water status. These strategies are similar to that used in the study by Singels and Smith (2006). The variable strategy represents the actions of a farmers receiving advice from ***MyCanesim*** while the fixed strategy represents the actions of a farmer not receiving advice.

7.2.2. Service impact assumptions for follow up analysis

Actual irrigation water use and yield data for Pongola small-scale farmers (see chapter 5) were not available when Fourie and Grové (2008) conducted their study and suggest very different trends than what was assumed by them. On average, subscribers to advice increased water use (approx. 130 mm) and yield (approx. 8 t/ha) in response to the advice, while the feasibility study assumed a large reduction in water (584 mm) and practically no change in yield. Socio-economic and infrastructure factors constrained water use and therefore the impact that advice had in the last two years.

No actual data was available for commercial farmers, but we can speculate that the assumptions made for the feasibility study are closer to the mark for commercial farmers because they are typically not constrained in a socio-economic and infrastructural sense to the same extent as small-scale farmers. Nevertheless, we felt it prudent to use the feasibility spreadsheet model of Fourie and Grové (2008) to re-calculate the monetary and net benefit of service subscription for various service impact assumptions sets. These were:

- CY and IWU impacts taken as the difference in CY and IWU measured for monitor and for non-participants at Pongola in 2004/05,
- CY and IWU impacts taken as the difference in CY and IWU measured for monitor and for non-participants at Pongola in 2005/06,
- CY and IWU impacts taken as the difference in CY and IWU simulated for monitor participants using an ideal irrigation schedule (see section 4.3.7) and the actual irrigation schedule,
- IWU savings of 300 mm and no impact on yield, and
- IWU savings of 200 mm and no impact on yield.

7.2.3. Service implementation options

Two service implementation options were considered. Firstly an “advice only” service where advice is disseminated by SMS to Pongola small scale farmers and by e-mail or fax to Heatonvile/Nkwaleni commercial farmers with dedicated field agents visiting farmers once every two weeks to discuss advice and irrigation practices and to obtain data to feedback into the ***MyCanesim*** system. This implies that farmers must inform the system or field agents of deviations from advice and, that commercial farmers provide feedback on actual irrigation schedules and rainfall via e-mail or web uploads. The second service option is an “advice plus field monitoring” option which consist of advice dissemination similar to option 1, but with electronic field monitoring of soil water status and rainfall, and weekly visits by field agents.

7.2.4. Subscription scenarios

Three subscription scenarios, consisting of combinations of numbers of small-scale and commercial fields, were investigated. For the “Advice only” service option these were (1) 50 small-scale fields plus 100 commercial fields, (2) 100 small-scale fields plus 200 commercial fields, and (3) 500 small-scale fields plus 300 commercial fields. For the “Advice plus monitoring” service the scenarios were 100, 200 and 300 commercial fields each, with no small-scale fields. Field size was assumed to be 10 ha each in all cases.

Irrigation costs were assumed to be directly proportional to volumetric water use and was based on 2006/07 costs to Pongola small-scale farmers (R.266/m^3 or R2.66/mm).

7.3. Results from by Fourie and Grové (2008)

The main simulated impact of the advice was a reduction in water use (on average 584 mm or 37%) and associated irrigations costs (on average R1544/ha). The calculated mean monetary benefit of service subscription was R1434/ha. These impacts were greater for the deep soil than for the shallow soil and it was greater in wet seasons than in dry seasons.

Service implementation costs depend on the type of service provided and the level of subscription. The annual cost of providing the “advice only” service varied from R0.972 million to R3.066 million as the subscription level increased from 1500 to 8000 ha. Total costs mainly consist of 70% human resource cost (system administrator and field agents) and 28% operational costs. The subscription cost, based on full recovery of service implementation, decreased from R649/ha to R384/ha when subscription to the service increased from 1500 ha to 8000 ha.

The “advice plus field monitoring” service option is much more costly due to increased frequency of field visits and the costs of instrumentation. It varied from R1.314 million to R2.995 million as the subscription level increased from 1000 to 3000 ha. Total costs consist of 60% human resource cost, 25% operational cost and 14% capital cost. The subscription cost, based on full recovery of service implementation, decreased from R1314/ha to R988/ha when subscription to the service increased from 1000 ha to 3000 ha.

Results suggest that benefit to cost ratio (BCR) for farmers of subscribing to the "advice only" service exceeds 2:1 for all subscription scenarios. For the given set of assumptions it therefore seems that providing such a service is feasible because the cost of service provision could be recovered from farmers and farmers would gain a significant net benefit from it.

For the "advice plus field monitoring" service option, mean net benefit was positive and BCR exceeded 1:1, but only barely so. The financial feasibility of this option is much more doubtful and depends strongly on the level of subscription to the service. The highest BCR achieved for this option was 1.51:1 for the deep soil and high subscription level.

7.4. Results from follow up analysis

As mentioned previously, the results obtained by Fourie and Grové (2008) were strongly influenced by the impact assumptions made and should be treated with caution. Calculations were redone using different, hopefully more realistic, sets of assumptions regarding the impact of the service. These results are shown in Table 7.1 together with results obtained by Fourie and Grové (2008) for the deep soil, for comparison.

It is evident from Table 7.1 that increases in cane yield have a far greater influence on net benefit from service subscription than reductions in water use. The actual responses in yield observed at Pongola and the potential response simulated for monitor participants, imply positive net benefits for the "Advice only" service for all subscription scenarios and for most scenarios for the "Advice plus monitoring" service, and suggest that full cost recovery from subscribers would be possible. The model suggests that a yield increase of as small as 4 t/ha (from a base line yield of 100 t/ha achieved from an IWU of 1000 mm) would results in positive net benefits for all subscription scenarios.

Table 7.1 The monetary and net benefit (R/ha) of two service options for different subscription scenarios and service impact assumptions (defined by irrigation water use [in mm] and cane yield [in t/ha] achievable for serviced and unserviced farmers).

Subscription scenario	**1**	**2**	**3**
Impact assumption set	**Fourie and Grové (2008), deep soil**		
Irrigation serviced	929		
Irrigation unserviced	1554		
Cane yield serviced	122		
Cane yield unserviced	123		
Monetary benefit	1357		
Net benefit service option 1	706	867	971
Net benefit service option 2	40	277	356
Impact assumption set	**2005/06 monitors *vs.* non-participants**		
Irrigation serviced	880		
Irrigation unserviced	720		
Cane yield serviced	92		
Cane yield unserviced	83		
Monetary benefit	899		
Net benefit service option 1	251	412	516
Net benefit service option 2	-415	-178	-99
Impact assumption set	**2004/05 monitors *vs.* non-participants**		
Irrigation serviced	970		
Irrigation unserviced	901		
Cane yield serviced	107		
Cane yield unserviced	92		
Monetary benefit	2577		
Net benefit service option 1	1929	2090	2194
Net benefit service option 2	1263	1500	1579
Impact assumption set	**2006/07 monitors ideal *vs.* actual**		
Irrigation serviced	815		
Irrigation unserviced	562		
Cane yield serviced	114		
Cane yield unserviced	91		
Monetary benefit	3678		
Net benefit service option 1	3030	3191	3294
Net benefit service option 2	2364	2600	2679
Impact assumption set	**Irrigation saving of 200 mm**		
Irrigation serviced	900		
Irrigation unserviced	1100		
Cane yield serviced	100		
Cane yield unserviced	100		
Monetary benefit	341		
Net benefit service option 1	-307	-146	-42
Net benefit service option 2	-973	-736	-657
Impact assumption	**Irrigation saving of 300 mm**		
Irrigation serviced	800		
Irrigation unserviced	1100		
Cane yield serviced	100		
Cane yield unserviced	100		
Monetary benefit	608		
Net benefit service option 1	-40	121	225
Net benefit service option 2	-706	-469	-390

Water savings of up to 300 mm did not result in positive net benefits, even at the relative high cost of irrigation assumed here (R2.66/mm), and a full cost recovery from subscribers would therefore not be feasible.

7.5. Conclusion

The study by Fourie and Grové (2008) suggest that farmers can obtain a positive net benefit from the "Advice only" service. The benefit of the more costly "Advice plus monitoring" is more doubtful. These results are based on the assumption that the service will result in a saving of 584 mm of irrigation water per season. Model recalculations with more realistic impacts show that a full cost recovery for the "Advice only" service would only be feasible in scenarios where cane yield can be increased, (by as little as 4 t/ha) by optimal scheduling. It is unlikely that service implementation costs can be fully recovered from irrigation water savings only.

Only direct impacts of service provision were considered here. However, the indirect benefits of such an advisory service cannot be under-estimated. It will promote efficient and productive use of water in a water-scarce country and will limit environmental degradation. It could be argued that these indirect benefits may justify that some of the service implementation costs be carried by the sugar industry generally or by the state.

8. CONCLUSIONS

8.1. System development

The ***MyCanesim*** system was successfully improved by developing and implementing a user-friendly, web-based graphical user interface that allows users to set up simulation runs, manipulate simulation input data and view various system reports (including irrigation advice). Extension staff and other role-players were involved in the design and testing of the interface.

A control module was created to allow for the smooth operation and monitoring of the ***MyCanesim*** system. It allows the system administrator to activate or deactivate schemes and fields listed for batch running, edit key field input variables such as cell numbers and harvest dates, edit historic irrigation schedules and manage advice dissemination.

A facility was also developed that enabled farmers to send a blank SMS reply to the ***MyCanesim*** system when they chose not to, or could not, follow the advice. The reply is automatically interpreted in the context of the specific advice and then used to adjust assumed irrigation records used as simulation input. The facility works correctly but has seldom been used by farmers, in spite of numerous instances when it was called for to do so.

Although the ***MyCanesim*** system executed successfully more than 95% of the time, there is room for code optimisation to reduce runtime. There is also a need for more powerful processing power to speed up execution speed to accommodate all prospective users.

8.2. System implementation: Pongola

The system was implemented fully on the Pongola small-scale irrigation scheme. Subscription to the service grew steadily from 5 in 2005 to 41 in 2008. Several challenges were met during implementation. Amongst these were:

- Difficulty in obtaining good quality irrigation and rainfall data timeously from farmers. This affected the accuracy of simulations and the relevance of advice.
- Conflict created in some cases by generating independent (and, at times, contrasting) advice to farmers who shared pumps. This problem can be overcome by making code changes that will synchronise advice as far as possible.

- Unreliable fax and inadequate Internet access was a problem for extension staff at both schemes.

It also became clear during implementation that regular and meaningful interaction between project technicians or extension staff and farmers are crucially important to maintain enthusiasm and assist with interpretation and practical implementation of advice.

The project helped extension staff and farmers gain a much better understanding of the important factors that determined the crop water balance and how irrigation can be scheduled to impact positively on productivity and sustainability.

The various reports available from the system provide concrete information (albeit simulated) for extension staff to benchmark irrigation practices, growth and yield of individual fields. The simulated results provided a good basis for discussion with farmers during field visits to identify agronomic practices that limited yields such as poor crop stand, insufficient weed control, erratic movements of sprinklers and excessive sprinkler stand times leading to alternating periods of waterlogging and drought.

A demonstration field day held in Pongola on 5 September 2007 was attended by 130 small-scale farmers and other interested persons from Mpumalanga, Makhathini flats and Pongola. Project team members explained the objectives of the project and how the ***MyCanesim*** system works. Three fields were visited and farmers explained how they participated in the project and benefited from the advice. This event stimulated the curiosity of farmers from other areas and exposed them to the potential of irrigation scheduling to improve yields, cut costs and improve the profitability of their businesses.

Observations of canopy cover, soil water status and cane yield in four fields in 2005/06, and in nine fields in 2006/07, show that model simulations of these variables were reasonably accurate when the Canesim model was supplied with accurate input data. Simulated canopy cover and yield compared well with observed values. Wetting front detector responses suggest that the Canesim model sometimes underestimated soil water status and it is recommended that this problem be further investigated with a view to improve the model.

The study showed that, for Pongola, the spatial variation in rainfall was low and that rainfall data recorded by a single automatic weather station was sufficient for accurate simulations. The study also showed the importance of accurate irrigation data input. It proved quite difficult to obtain timeous and reliable irrigation data from farmers. Assumptions that farmers followed advice to irrigate or not were not always correct and this led to incorrect simulations and advice about 5% of the time. The main reason for farmers not following advice was lack of water supply when advised to irrigate. The cause of this was electricity cuts due to non-payment, pump breakdowns and interruptions in water supply at scheme level.

Factors outside the scope of this study unfortunately played a dominant role in the long-term trends in water use and cane yield observed on the Pongola scheme. Declining water availability, changed method of payment for water and lack of infrastructure maintenance contributed to a general decline in irrigation water use and yield. However subscribers to the service experienced slower rates of decline and applied more water and achieved higher yields than non-subscribers. This suggests that the advisory service had a beneficial impact on the productivity and profitability of farmers who subscribed to the service.

8.3. System implementation: Makhathini

Implementation at Makhathini was problematic. Five fields were monitored in 2005/06 and advice was provided to an equal number of farmers. However, only two farmers out of twenty-three that were evaluated, fulfilled the criteria for monitor participants, and in 2006/07 only two fields were monitored. The main problem was inadequate irrigation systems that result in excessively long irrigation cycles that exceed the design specifications by two or threefold. In practice, this amounts to supplementary irrigation. Irrigation was often also stopped entirely midway through the growing season because sprinkler stands were too short to distribute water above the cane canopy.

Another frustration was the unavailability of quality data at field and scheme level. It was very difficult to obtain reliable irrigation and rainfall data during the 1st season (2005/06) because it was difficult to make farmers understand the trial objectives and methods. The integrity of yield data at a scheme level was questionable, while no water use data was available. Further, it was impossible to obtain harvest schedules in advance. This made effective research and service provision impossible. It was therefore decided to terminate field monitoring in May 2007, while advice is still provided to all farmers that subscribed.

Most Makhathini farmers were unable to benefit from the advice because the irrigation systems are inadequate to supply the required amount of water. It is estimated that on average, farmers could and should have applied approximately 85% more water, even with the long irrigation cycles of existing systems. This caused an estimated yield shortfall of 60%. The estimated irrigation and yield shortfalls are much larger when benchmarked against ideal irrigation schedules with the specification cycle of 7 days. Despite numerous attempts to convince participants to upgrade and repair irrigation systems and to improve crop husbandry, nothing has changed. Lack of land ownership, lack of cash flow and a 12-hour per day water supply are severe limitations to correcting these problems.

8.4. Farmer survey

Interviews with 20 Pongola farmers showed that most farmers found the irrigation advice useful and easy to understand, and trusted the advice most of time. The project made farmers more aware of the importance of irrigation scheduling in increasing revenue and reducing costs, and most farmers say that they have changed irrigation practices because of the advice. The majority of farmers indicated that they wanted the service to continue and were prepared to pay a small service fee.

8.5. Economic feasibility study

The study suggests that farmers can obtain a positive net benefit from the “Advice only” service. The benefit of the more costly “Advice plus monitoring” is more doubtful. These results are based on the assumption that the service will result in a saving of 584 mm of irrigation water per season. Model recalculations with more realistic impacts show that a full cost recovery for the “Advice only” service would only be feasible in scenarios where cane yield can be increased by better scheduling. Yield increases of as little as 4 t/ha would pay for the cost of the service. It is unlikely that service costs can be fully recovered from irrigation water savings only.

8.6. General

The approach used here for developing and implementing an irrigation decision support system proved highly appropriate. The fact that users were involved in the design and implementation and the fact that system complexity was hidden from users contributed to quick and wide adoption of the technology. It was also shown that there is no need to scale down technology when providing decision support for small-scale farmers. In fact, modern technologies such as the Internet, cellular communication, electronic weather stations and crop models made it possible to develop a system that addressed the unique needs of small-scale farmers and their agents and to overcome many constraints.

It is believed that this type of irrigation scheduling advisory service (as provided to Pongola small-scale farmers) has many indirect benefits (reduced soil degradation, reduced leaching of nutrients) that were not monitored in this project. The study showed that significant direct (monetary) benefits are possible, provided the following prerequisites are in place:

- Reliable and adequate supply of water,
- Adequate irrigation systems,
- Adequate control over water supply and irrigation at the field level,
- A sense of ownership of land and infrastructure,
- Monetary incentives for farmers to benefit from water savings,
- Willingness of farmers or water use agencies to contribute to the cost of service delivery,
- Competent and committed support from field support agents that are needed to assist farmers with implementing advice and to obtain accurate field data,
- Adequate Internet access and fax facilities for field support agents, and
- Adequate computer processing power and optimal system code to reduce system run time and enable system expansion.

The project provided ample opportunity for capacity building (see Appendix 11.8 for full details). The 47 farmers from Pongola and Makhathini that were directly involved in the project enhanced their knowledge and skills needed for irrigated sugarcane farming. KZN DAEA and Illovo mill extension staff learnt how to use crop and weather data to assist them in their job. Project researchers learnt more about participative research, while the two project technicians learnt how to interact with farmers and capture and process field data. Both technicians (shown in Fig. 8.1) have also furthered their studies one towards a diploma, and the other a degree in Agriculture.

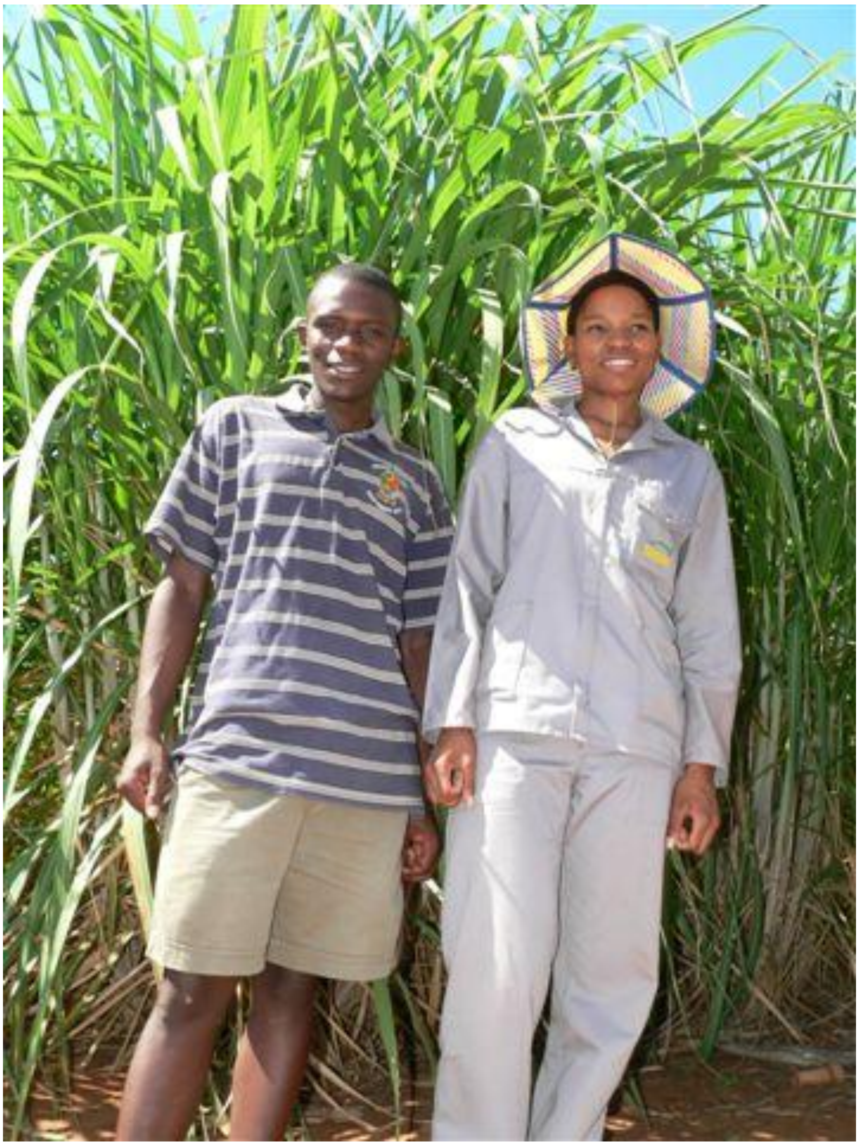


Figure 8.1 SASRI technicians David Kaptein and Dumisile Mthembu.

9. RECOMMENDATIONS

An advisory service that provides real time irrigation scheduling advice based on weather data can be implemented on other sugarcane irrigation schemes, provided that the concerns mentioned in Chapter 8 are addressed. It is recommended that:

- The issues of landownership, inadequate irrigation infrastructure and inadequate or inflexible water supply are resolved first before considering the implementation of an irrigation scheduling advice service.
- Modern broadband technology is implemented to address the inadequate Internet bandwidth at support agencies in rural areas.
- Fax machines of the KwaZulu-Natal Dept of Agriculture Office in Pongola are fixed and properly maintained.
- Staff from government agencies (such as Water Users' Associations, Dept. of Water Affairs and Dept. of Agriculture) and sugar industry organisations (such as SASRI and Milling companies) are trained to understand and use the ***MyCanesim*** system. Apart from providing real time scheduling advice, it could also provide information to predict water use and yields and compare these to actual yields and water use.
- The use of electronic equipment are explored to monitor irrigation and rainfall at a field level and integration of this data into the ***MyCanesim*** system to improve the quality of simulation output and advice.
- Aspects of the system are customised to address the unique needs of each irrigation scheme or scenario. This requires involvement by potential users (farmers and their support agents) and a phased implementation.
- Full cost recovery of such a service is unlikely under the current scenario. Subsidisation by role-players who have an interest in more efficient use of irrigation water must be considered, or alternatively, a scheme should be devised to provide a better incentive for farmers to subscribe to such a service.

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11. APPENDIX

11.1. *MyCanesim* system components

Table 11.1.1. A description of the different procedures in the *MyCanesim* system. Procedures are grouped into functional algorithms and interact with data tables.

Algorithm name	Algorithm function	Procedure name	Procedure function	Data table reference
Reply interpretation	Receives SMS from the farmer, and then adds or removes an irrigation from the schedule and changes the state of farmers irrigation (irrigating or not irrigating)	Main	Receives the SMS as email, logs the SMS. Replies to the farmer with an appropriate SMS.	CS_SMS_REC_LOG, CS_FIELD_SCENARIOS
		didIrrYesterday	Determines whether the farmer irrigated on the previous day	CS_SMS_IRRIG, CS_IRRIGATION_HISTORIES
		deleteIrr	Removes the previous days irrigation. Sets the farmers irrigation state to not irrigating	CS_SMS_IRRIG, CS_IRRIGATION_HISTORIES
		addIrr	Adds irrigation for the previous day. Sets the farmers irrigation state to irrigating	CS_SMS_IRRIG, CS_IRRIGATION_HISTORIES
Control Module	This module provides a dashboard on the current state of all farmers. A log of SMS sent to a farmer may be accessed and the irrigation schedule of a farmer may be modified.	GetNames	Returns the details of all farmers for whom irrigation is being scheduled.	CS_SMS_IRRIG, CS_FIELD_SCENARIOS
		doRecalc	Recalculates a farmers irrigation schedule from changes made to the irrigation calendar	CS_SMS_IRRIG, CS_IRRIGATION_HISTORIES
Drying off	To calculate dry off initiation for the current crop	findDryOff	Find the day on which the dryoff should begin.	CS_WEATHER_MEASUREMENTS
		calcDryOff	Calculates the long-term mean accumulated daily water deficit for each crop day.	CS_SMS_IRRIG,
		DryOffTime	Determine if the field is currently in a drying off state.	CS_IRRIGATION_HISTORIES
Fill up irrigation profile	Algorithm to fill up soil water profile before allowing normal irrigation scheduling to stop irrigation	HasFulledProfile	Calculates if the irrigation profile has been filled.	
Irrigation Scheduler	Algorithm to determine daily irrigation schedule	CalcIrriDaily	Determines dates to start an irrigation cycle	
		GetCurrentState	Determine whether irrigation has been scheduled for the current date.	
		FindStart	Find the date on which scheduling was	

		FindPos GetUserState executeRuns	last run. Determine the current position of irrigation in the field. Gets the users current override preference Re-runs the simulation for a given field	 CS_SMS_IRRIG CS_RESULT_DETAILS
Provide farmer advice	Determines what advice a farmer should receive according to whether calculated irrigation schedule, or whether he should receive a weekly confirmation SMS	DoAdvice GetFinalYield GetCurrYield GetCurrDate MessageSender	Primary procedure to determine the contents of an SMS. Returns the final yield for a field Returns the yield today for a field Returns the date for a given index position Sends a compiled message to the farmer's address, and logs the message details.	CS_IRRIGATION_HISTORIES, CS_SMS_IRRIG CS_RESULTS_DETAILS CS_RESULTS_DETAILS CS_SMS_LOG
Fax Advice / Irrigation Report	Once a week a summary of the farmer details, information on their current irrigation status and future irrigation information is faxed to the relevant EOs, technicians and advisors. The same information is updated daily in database tables to be accessed from the *MyCanesim* internet interface.	GetSumInfo GetCurInfo GetDryOff GetDays GetCurrAction GetIrriStop GetIrriStart AddDays	This method generates the "Irrigation advice and current estimates" table for the fax and database table This method generates the "Field properties and final estimates" table for the fax and database table Finds the date on which the farmer commences his dry off. This is returned to the GetCurInfo method above. Used to convert dates between Oracle and .Net formats. Determines whether a farmer is currently irrigating Determines on what date a farmer will stop irrigating Determines on what date a farmer will start growing Used to add days to a date.	CS_FIELD_SCENARIOS CS_RESULTS_DETAILS CS_SMS_IRRIG_TABLE_FUTURE CS_FIELD_SCENARIOS CS_RESULTS_DETAILS CS_SMS_IRRIG CS_SMS_IRRIG_TABLE_CURRENT CS_FIELD_SCENARIOS CS_IRRIGATION_HISTORIES CS_SMS_IRRIG CS_FIELD_SCENARIOS CS_IRRIGATION_HISTORIES CS_FIELD_SCENARIOS CS_IRRIGATION_HISTORIES

Table 11.1.2. A description of the different data tables in the *MyCanesim* database.

Data table	Variable names
FIELD_SCENARIOS	SUGAR_FARMER_CODE SUGAR_FARM_NUMBER FIELD_SCENARIO_CODE DESCRIPTION NOTIFICATION_ADDRESS NOTIFICATION_CYCLE NOTIFICATION_START_DATE TAM SATURATED_WATER_CONTENT FIELD_WATER_CAPACITY WILTING_POINT CLAY_CONTENT SILT_CONTENT BULK_DENSITY EFFECTIVE_ROOTING_DEPTH START_DATE HARVEST_DATE WEATHER_STATION RAIN_GAUGE_ID IRRIGATION_BLOCK_ID AUTO_IRRIGATION TYPE_OF_IRRIGATION EMITTER_DEPTH EMITTER_SPACING LINE_SPACING IRRIGATION_TIMING REFILL_LEVEL DEPLETION_LEVEL IRRIGATION_CYCLE FIXED_MM AGRONOMIC_PARAMETERS VARIETY_CODE ROW_SPACING PLANT_OR_RATOON_INDICATOR FORECAST_TYPE FORECAST_CONDITION FORECAST_PERIOD RUN_DATE_TIME LAST_WEATHER_DATE NEXT_IRRIGATION_DATE NEXT_IRRIGATION_AMT CURRENT_IRRIGATION_AMT FINAL_IRRIGATION_AMT CURRENT_RAINFALL_AMT FINAL_RAINFALL_AMT INITIAL_SW_CONTENT
CS_SMS_IRRIG	SUGAR_FARMER_CODE FIELD_SCENARIO_CODE IRRIGATION_POSITION

	IRRIGATION_STATE LAST_RUN_DATE COMMIT_DATE USER_OVERRIDE TEMP_INDEX
CS_RESULTS_DETAILS	SUGAR_FARMER_CODE SUGAR_FARM_NUMBER FIELD_SCENARIO_CODE RUN_DATE_TIME DAILY_DATA_DATE WS_MISSING_DATA_INDICATOR PLANNED_IRRIGATION CROP_AGE CUM_EVAP_TRANS CUM_IRRIGATION CUM_RAIN CUM_SOIL_WATER CUM_CROP_WATER_USE CANE_YIELD SUCROSE_YIELD DRY_MASS ACTUAL_OR_FORECAST FORECAST_YEAR SOIL_WATER CANOPY_PERC STRESS SUCROSE_CONTENT_PERC DRY_MATTER_PERC MISSING_RAINFALL_PERC MISSING_RADIATION_PERC MISSING_WIND_PERC MISSING_HUMIDITY_PERC MISSING_TEMPERATURE_PERC MISSING_EVAP_TRANS_PERC DRAINAGE CUM_TT LODGE
CS_IRRIGATION_HISTORIES	SUGAR_FARMER_CODE SUGAR_FARM_NUMBER BLOCK_ID IRRIGATION_DATE IRRIGATION_AMOUNT
CS_SMS_LOG	DATE_SENT RECEIVING_ADDRESS MESSAGE_CONTENTS RECIPIENT
CS_WEATHER_MEASUREMENTS	STATION_ID WEATHER_DATE SOURCE_CODE MAX_TEMP MIN_TEMP

	RAINFALL RADIATION WIND TEMP_W8 TEMP_D8 TEMP_W14 TEMP_D14 REL_HUMIDITY_8 REL_HUMIDITY_14 MIN_REL_HUMIDITY MAX_REL_HUMIDITY MEAN_VAPOUR DAILY_EVAPORATION APAN_EVAPORATION SUNSHINE_HOURS GROWTH MISSING_DATA_CODE SWC60 SWC100 SWC140 PATCH_INFO
CS_SMS_IRRIG_TABLE_CURRENT	SUGAR_FARMER_CODE FIELD_SCENARIO_CODE DESCRIPTION CURRENT_ACTION NEXT_ACTION NEXT_ACTION_DATE DRY_OFF RAIN IRRIGATION YIELD USER_OVERRIDE
CS_SMS_IRRIG_TABLE_FUTURE	SUGAR_FARMER_CODE FIELD_SCENARIO_CODE DESCRIPTION SYSTEM IRRIGATION_CYCLE IRRIGATION_APPLICATION TAM START_DATE HARVEST_DATE RAIN IRRIGATION

11.2. Report on farmer meetings held in 2006

The purpose of the workshops was to:

- assess progress with the implementation of the ***MyCanesim*** irrigation advice service in Pongola and Makhathini, and to plan project operations,
- educate farmers so that they would understand the advice and would be able to interpret and react to it, and
- determine whether it would be feasible to continue with the project in Makhathini.

These workshops were held on 27 June at the Ntonga Club, Pongola Mill and on 28 June at Mjindi Farming in Makhathini. A summary of the main issues from each meeting follows.

11.2.1. Pongola

<u>Achievements and challenges</u>

Progress was reviewed by comparing achievements with original project objectives. The following achievements were highlighted:

- ***MyCanesim*** computer system was improved (improved user interface, system control module, an algorithm to determine the best date to cease irrigation, a module to accept information feedback from farmers).
- Twenty-eight farmers were subscribed to the service on 27 June, while four participated as monitor farmers where field measurements were taken. Two of these followed advice closely, namely Mthembu and Simelane. All farmers demonstrated an increased awareness of the benefits of irrigation scheduling, which could be ascribed to the project and the farmers' interactions with project team members. Farmers pushed for some financial reward to water saving, which resulted in a positive change in payment methods.

- The following problems were also discussed:
- Too few monitor participants – Farmers were informed that more participants were needed and that field assessments will be conducted on volunteers. The aim is to have 8 monitor participants.
- Poor quality of field recordings – This serious problem has been addressed by getting SASRI technicians to take the readings *in situ* once a week. Owners are encouraged to be present when recordings are taken.
- Non-adherence to advice – Nene and Khumalo practised 24-hour stand times, resulting in excessively long irrigation cycles and high application rates. It also caused the simulation of their situation to be non-representative. The issue was

discussed with them and they agreed that it would be better to revert to a 12-hour stand time.

- Pump sharing: Most farmers share pumps (and the operating cost) with neighbours, and although they do have individual valve control, conflicts have arisen. The project team will look into the possibility of synchronising advice for farmers who share pumps to minimise opportunities for conflict.
- Harvest dates: Harvest dates are confirmed or changed too late for the system to calculate reliable drying off advice. The project team, together with farmers and Pongola mill staff, explored with the farmers possible procedures to overcome this. The resignation of key staff from the mill and the appointment of new harvesting contractors complicated the situation. The new mill staff member (Etienne de Beer) undertook to meet with contractors to update estimated harvest dates on a weekly basis.
- Calculation of canopy cover: Comparison of simulated values of canopy cover with measurements shows that the model overestimates canopy development in summer and underestimates in winter. This applies to the period of partial canopy only. This will be fixed by introducing a maximum cap on temperatures that are deemed as effective for driving canopy development and recalibrating the model to the observed values.
- System down time – Bugs in the program as well as computer network and server problems were causing the system to execute only partially or fail completely, on some occasions. Various bugs in the system were fixed by contracting Marc Smith. SASRI IT will be asked to address the computer network and server problems.

<u>Results to date</u>

The simulated water balance of all monitor participants was discussed to highlight good practices as well as opportunities for improvement. The example for Mthembu is shown in Fig. 1. He over irrigated early in the season but followed advice thereafter more closely. There were also periods where water was not available and water content dropped below the target zone.

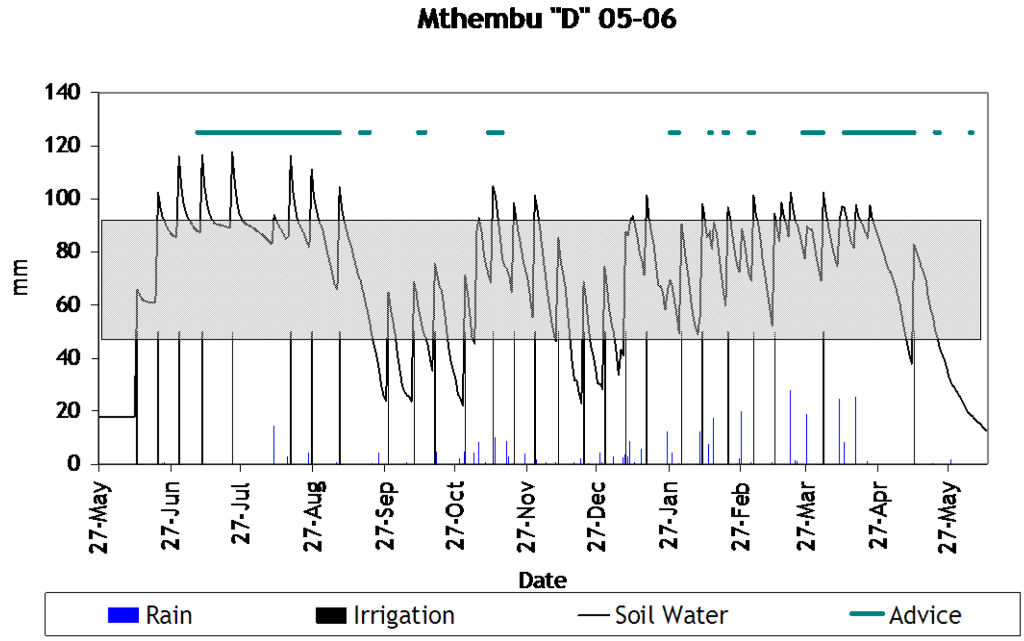


Fig. 1. The simulated water balance for Mthembu.

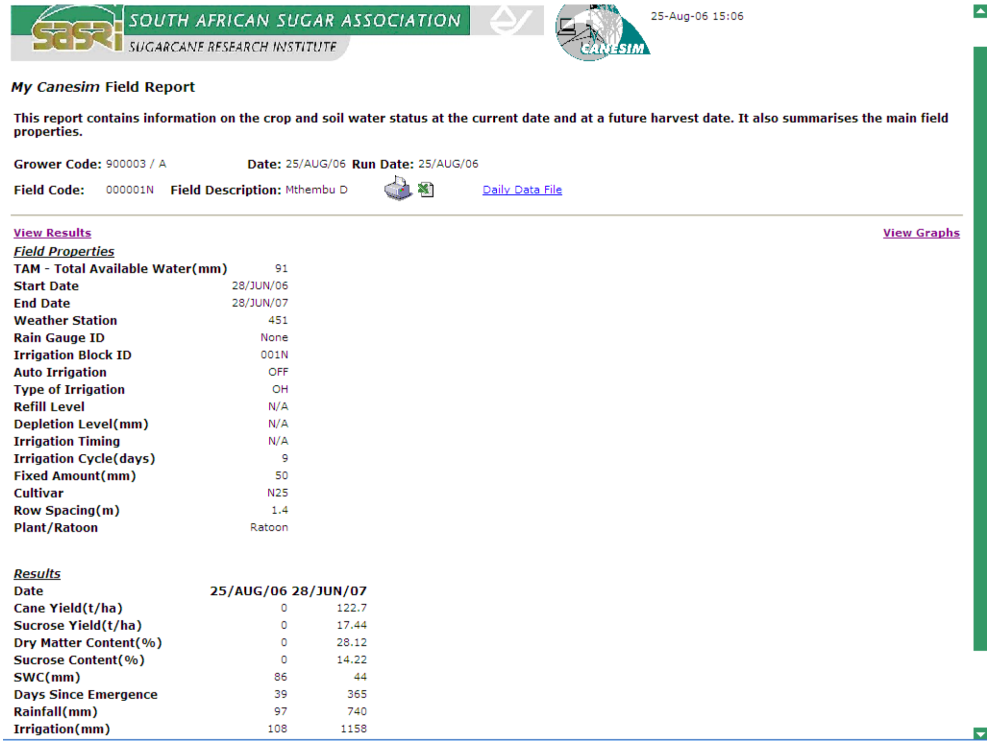
The impact of irrigation and yield was demonstrated with data from the four monitor participants (see Table 1). It clearly showed that Mthembu applied too much water. The other farmers applied close to the advised amount, although there were deviations from the advice for Nene and Khumalo. The model predicted that most farmers should achieve yields close to the potential. It is interesting to note that yield determined through a sampling of a 6 m row length was much higher than simulated yields. Mill data will be obtained to verify these yield estimates.

Table 1. Advised (best) irrigation and the resulting simulated cane yield, compared to the estimated irrigation that the farmer actually applied and the simulated cane yield resulting from that. The sampled yield is also given.

Farmer	Best Irrigation (mm)	Best Yield (t/ha)	Farmer's Irrigation (mm)	Farmer's Yield (t/ha)	Sampled Yield (t/ha)
Mthembu	1134	124.7	1400	120.6	169
Simelane	966	100.1	1092	96.3	116
Nene	1092	128.9	1092	125.6	
Khumalo	1029	125.7	1134	118.7	

System reports

Each farmer received a hard copy of an up to date system report for his field. An example is shown in Fig. 2. The various input parameters and output from the system was explained and discussed. Farmers were encouraged to ask their Extension officer or SASRI technicians if they had any questions



SOUTH AFRICAN SUGAR ASSOCIATION
SUGARCANE RESEARCH INSTITUTE
25-Aug-06 15:06

My Canesim Field Report

This report contains information on the crop and soil water status at the current date and at a future harvest date. It also summarises the main field properties.

Grower Code: 900003 / A Date: 25/AUG/06 Run Date: 25/AUG/06

Field Code: 000001N Field Description: Mthembu D Daily Data File

View Results View Graphs

Field Properties

TAM - Total Available Water(mm)	91
Start Date	28/JUN/06
End Date	28/JUN/07
Weather Station	451
Rain Gauge ID	None
Irrigation Block ID	001N
Auto Irrigation	OFF
Type of Irrigation	OH
Refill Level	N/A
Depletion Level(mm)	N/A
Irrigation Timing	N/A
Irrigation Cycle(days)	9
Fixed Amount(mm)	50
Cultivar	N25
Row Spacing(m)	1.4
Plant/Ratoon	Ratoon

Results

Date	25/AUG/06	28/JUN/07
Cane Yield(t/ha)	0	122.7
Sucrose Yield(t/ha)	0	17.44
Dry Matter Content(%)	0	28.12
Sucrose Content(%)	0	14.22
SWC(mm)	86	44
Days Since Emergence	39	365
Rainfall(mm)	97	740
Irrigation(mm)	108	1158

Fig. 2. Example of a printed sheet from the *MyCanesim* system that summarises simulated results for a given field.

Farmer survey

Farmers were informed that they will be asked to partake in a survey to assess their perceptions regarding the service and its impact on water use, cane yield and quality and economic benefit.

11.2.2. Makhathini

Farmers and other stakeholders were presented with the main achievements and problems of the project similar to what was done at the Pongola meeting. At Makhathini only three farmers (four fields) are involved as monitor participants, and one as an advice participant. A problem particular to Makhathini was the poor state of irrigation systems of most sugarcane farmers including the participants. This is dealt with later in this report.

Results

The simulated water balance of all monitor participants was discussed to highlight opportunities for improvement. Example for Mathenjwa and Myeni are shown in Fig. 3a and 3b. Seasonal totals are given in Table 2. It is clear that there were very few opportunities to save water because of the inadequate supply of water.

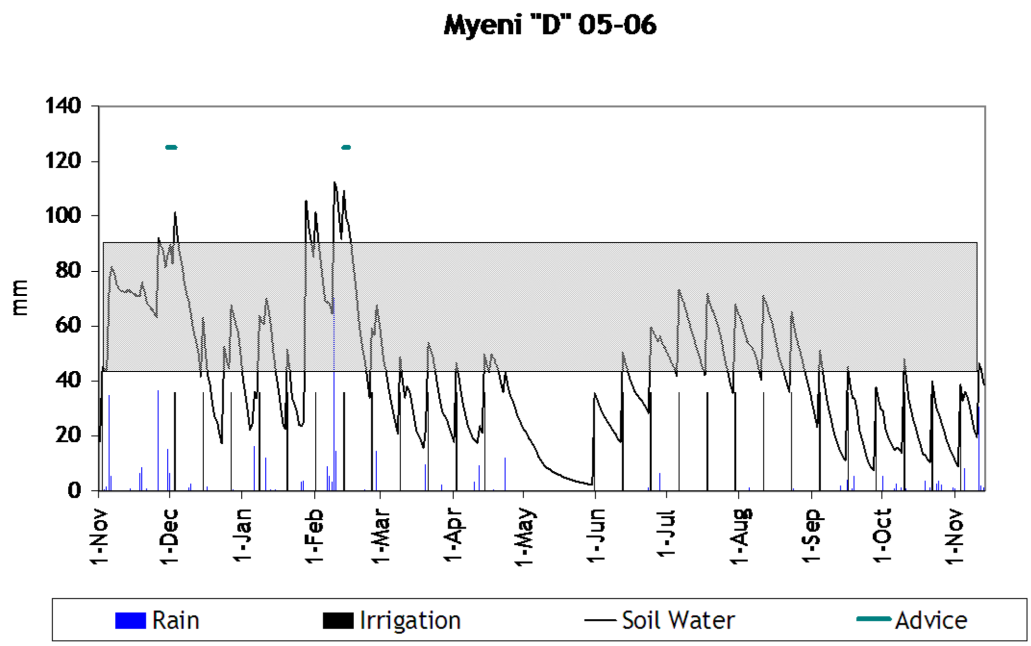


Fig. 3a. The simulated water balance for Myeni.

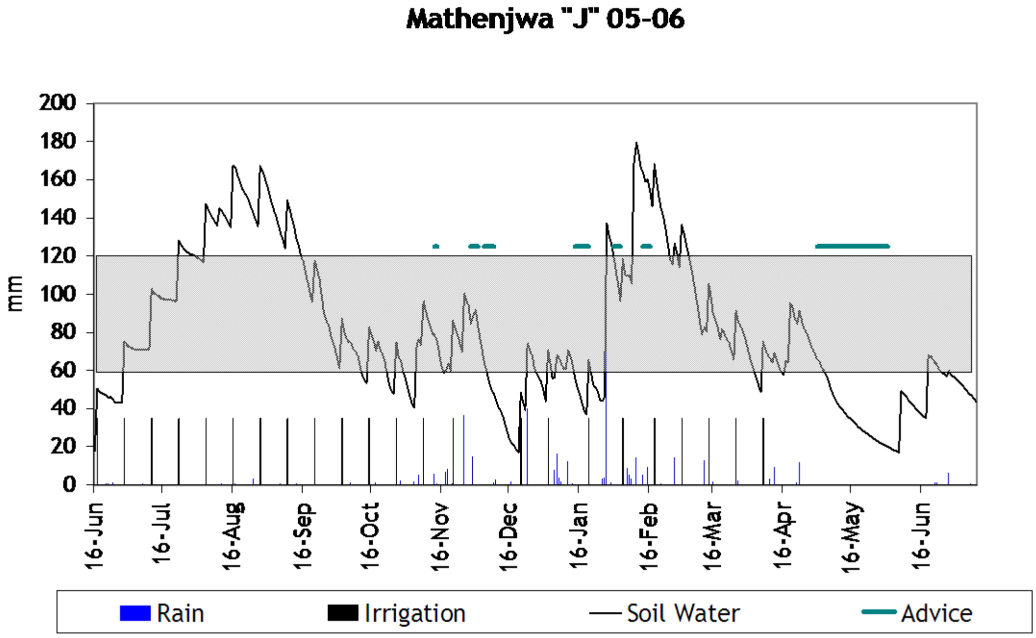


Fig. 3b. The simulated water balance for Mathenjwa.

The advice to Mathenjwa to stop irrigation for short periods in November and December 2005 was based on faulty weather data and was therefore incorrect. The fault has been rectified.

Table 2. Advised (best) irrigation and the resulting simulated cane yield, compared to the estimated irrigation that the farmer applied and the simulated cane yield resulting from that.

Farmer	Best Irrigation (mm)	Best Yield (t/ha)	Farmer's Irrigation (mm)	Farmer's Yield (t/ha)
Mathenjwa A	856	111	805	96
Mathenjwa B	856	111	864	100
Ngxongo	844	113	828	108
Myeni	984	116	540	64

Please note that advised irrigation takes into account inadequate irrigation systems. Ideal irrigation (original design) would be much higher and result in much higher yields.

The inadequacy of irrigation systems and the impact that this had on the relevance and impact of the advice was discussed at length. Farmers were unable to apply the required amount of water due to too few sprinklers (resulting in too long irrigation cycles) or short sprinklers (irrigation ceased as soon as cane is taller than sprinklers). The meeting decided that despite this situation, the project will continue, but with revised methodologies and objectives. Only farmers who fulfil the criteria stated in the minutes will be accepted as monitor participants. The current participants and future candidates will be screened according to these criteria. The project team will not be responsible for fixing or upgrading irrigation systems – this is the responsibility of farmers and their representatives.

11.2.3. Conclusions

Progress at Pongola has been excellent with the majority of farmers on the scheme receiving advice. Although the quality of recordings has been poor and the number of monitor participants too few, both these problems are being addressed. The problem of incorrect harvest dates is also being addressed.

At Makhathini, inadequate irrigation systems and practices led to severe under-irrigation. This makes the advice for water saving largely irrelevant. The project will continue but only farmers that fit minimum criteria will be accepted as participants. Current participants will be reassessed with respect to the same minimum criteria.

Farmers from both schemes demonstrated an increased awareness of the importance of efficient use of irrigation water and this is attributed to involvement with the project and to farmer's interaction with project team members. Farmers at Pongola are particularly keen to reduce their water use in order to save costs.

11.3. Extension reports

Visit to the plots of Mr Nene and Mrs Simelane, Pongola on 5 March 2007 by A. Singels, J. Neen, M. Eweg, R. Chiloane, N. Kaptein, D. Mthembu, TZ Nene and NM Simelane.

11.3.1. Mr Nene

1. Fertiliser Application

The farmer uses the hand broadcast method of applying fertiliser. It is suggested that if he finds he has under-applied fertiliser (e.g. by 10 bags, the equivalent to 1 bag/ha), that he goes back and spreads the “under applied” fertiliser as evenly as possible over the entire plot.

2. Waterlogged areas

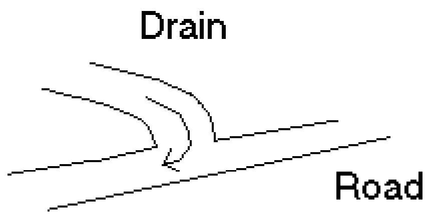
It was recommended that the farmer does not switch off the irrigation to the entire plot when the smaller portions of the field (about 20%) become waterlogged. Instead he continues to apply the recommended irrigation to the rest of the field and uncouples the sprinklers that would otherwise irrigate the waterlogged areas.

3. Encroachment into the waterway

It was noticed that the farmer had planted into the edge of the waterway. The farmer should determine (with Chiloane's help) how wide the waterway should be and remove any cane that encroaches into the waterway. The original design plans (probably on file in the Department of Agriculture Office) would indicate how wide the waterway should be.

4. Drains

The two drains that were seen contained cane and weeds. They should be cleared to allow the free flow of excess water. The point where they exit onto the road should be cleared of rubble and must be turned downwards so water flows and does not back up (see sketch).



5. Weeds

Weeds must not compete with the crop. Use a long-term pre-emergent herbicide (ask the local herbicide representative to recommend one) and apply the spray after harvest but before the weeds become visible. The herbicide should keep the weeds under control from early cane growth until the canopy forms (10-12 weeks). Do not wait until the weeds are big before spraying. There was some visual evidence of herbicide damage on the cane and Mr Nene admitted to having applied MSMA which is known to be a severe treatment.

6. Plot size

It will be useful to know the exact area of the plot. The area may be different to what Mr Nene believes it to be. Mr van de Merwe will be asked to provide a GPS unit and a technician to re-measure the plot.

7. Salinity test

It was recommended that the technician take a soil sample at 30 cm depth, 60 cm depth and 90 cm depth from the waterlogged area. The samples must be correctly marked using FAS tickets (blue) and submitted to FAS for analysis.

11.3.2. Mrs Simelane

1. Plot size

Plot size is not known for sure. The technician that re-measures Nene's plot will be asked to re-measure Mrs Simelane's plot as well.

2. Under application of fertiliser

The Mayfield applicator that is used by the farmer must be re-calibrated when the next fertiliser is to be applied to the plot. This will reduce the risk that an incorrect amount is applied. Use the fertiliser recommended to do this. Mr Chiloane will be able to assist the farmer.

3. Payment for Electricity

Mrs Simelane and neighbour Mr Nyawo must agree to an alternative system of paying for electricity. This is to avoid Mrs Simelane having the electricity to the shared pump turned off by Mr Nyawo whilst she is irrigating. The suggestion is that the electricity account be shared in accordance with the amount of water each farmer uses. Water usage is measured and the reading for each farmer should be available. Dr Singels offered to obtain flowmetre readings from the Impala Irrigation Board. For example if Mrs Simelane used 15 units of water and Mr Nyawo uses 10 units of water, Mrs Simelane should pay $^{15}/_{25}{}^{th}$ of the account and Mr Nyawo should pay $^{10}/_{25}{}^{th}$ of the account. It will be necessary to reconfirm the area measurement of Mr. Nyawo at this time. Richard Chiloane is to arrange to meet with these farmers to attempt to get a suitable agreement on a practice change.

4. Yield comparison

Mrs Simelane's farm has some very shallow and rocky soil and some soil which although rocky is a little deeper. It was recommended that when yield measurements are done, that they be taken from both sites, for the purpose of comparison. David will be responsible for this.

5. Irrigation stand time

Due to the very shallow nature of the soil on part of the farm it was suggested that it would be beneficial for the farmer to consider reducing the irrigation stand time (on this southern section above the road) from 12 to 6 hours. This would reduce the risk of run-off and allow for more efficient use of water by the crop. Dr Singels will use the model to simulate this.

6. Trashing

Trashing on the shallow soils of this plot could be very beneficial for the farmer and should be tried. Mr Eweg will determine if there are any requirements stipulated by the Miller with regard to the acceptance of trashed cane.

11.4. Information sheet for demonstration field day held on 5 September 2007

IRRIGATION SCHEDULING ADVICE TO PONGOLA SMALL-SCALE SUGARCANE FARMERS VIA SMS USING *MYCANESIM*

Project team: A. Singels, J. Neen, D. Mthembu, N. Kaptein, R. Chiloane, M. Smith, Y. Keleta

August 2007

Irrigation scheduling

- Definition: When to irrigate and how much to irrigate
- Aims: To ensure favourable soil water status (not too dry or not too wet) for high yield and quality
- Benefits: High cane yield, good cane quality, water saving, reduced fertiliser leaching, reduced deep drainage, reduced costs, less environmental degradation

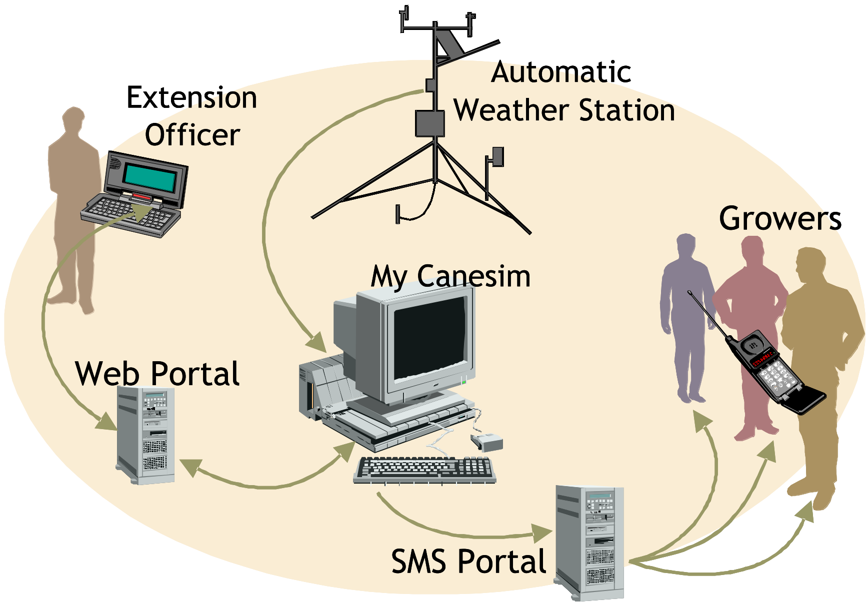
Pongola small scale irrigation scheme

- 47 farmers on 508 ha (approx 10 ha each)
- Semi permanent overhead systems, 10 day cycle, 42 mm net application
- Soils vary from poor to good. Cultivars: N19, N25, N26

Goals of SMS project

- To enable farmers and extension to reduce over-irrigation, reduce irrigation costs and maintain high yields by effective scheduling
- To develop, implement and evaluate a system that provides real time advice to farmers and extension

Overview of system

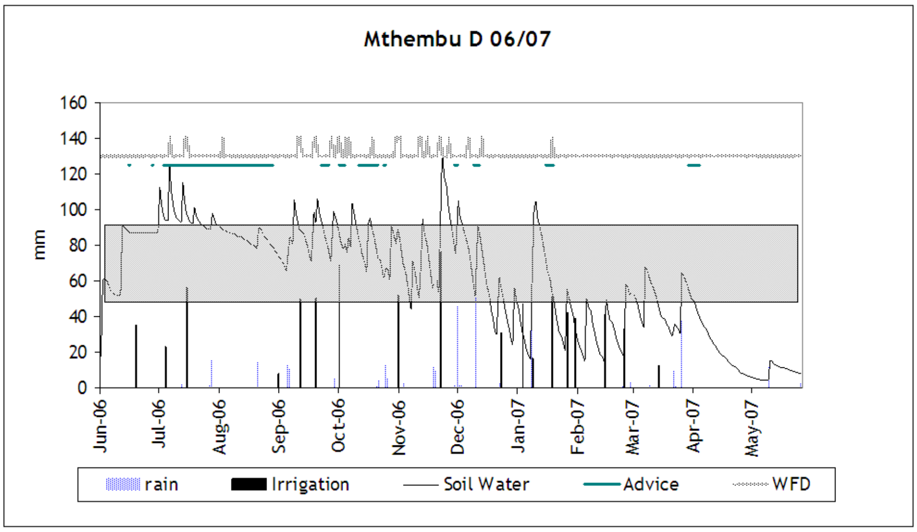


Challenges

- Data feedback from farmers essential for quality advice –not forthcoming
- Requirement for regular and meaningful interaction with farmers to maintain enthusiasm
- Pump sharing causes conflict
- Unreliable fax and Internet access

Results

Water balance



Water use and yields

				Irrigation (mm)		Cane yield (t/ha)		
Farmer	Harvest Date	Crop age (d)	Rain (mm)	**Rain gauge**	**Climatic req**	My Canesim	Mill	Climatic pot
1	28-Jun-06	397	511	**1424**	**1050**	113	126	119
2	1-Jul-06	322	495	**868**	**1008**	82	72	100
3	7-Dec-06	389	685	**831**	**1092**	105	93	141
4	17-Nov-06	347	602	**897**	**882**	113	79	121
1	22-Jun-07	359	803	**690**	**798**	98	112	121
2	06-Jun-07	354	803	**548**	**966**	96	73	114
5	10-Apr-07	330	738	**124**	**588**	75	84	108
6	25-Aug-07	361	703	**534**	**840**	88	116	127
7	22-Jun-07	359	803	**690**	**798**	98	112	121

Irrigation water use efficiency (IWUE) in 2005/06

	Cane yield (t/ha)	IWU (mm)	IWUE (kg/m3)
All	86.5	618	14.6
Non-participants	83.2	555	14.9
Advice participants	86.4	601	15.1
Monitor participants	94.1	847	11.1

Achievements

- Improved ***MyCanesim*** system
- Wide adoption (from 4 in 2004 to 38 in 2006)
- Improved understanding of the importance of scheduling by extension and farmers
- Increased awareness of cost of over-irrigation
- Benchmarking of practices, growth and yield possible
- Correction of suboptimal practices.

Acknowledgements: South African Sugarcane Research Institute, Water Research Commission, Illovo Sugar Ltd., KwaZulu-Natal Dept. of Agriculture and Environmental Affairs, Impala Water, Pongola small scale farmers

11.5 Questionnaire for farmer survey

SURVEY TO ASSESS THE ATTITUDES AND PERCEPTIONS OF SMALL SCALE SUGARCANE GROWERS ABOUT THE MY CANESIM IRRIGATION ADVICE SERVICE:

QUESTIONNAIRE FOR FARMERS AT PONGOLA

Compiled by O Poutaredy and A Singels
Interviews conducted by D Mthembu
November 2006

SURVEY TO ASSESS THE ATTITUDES AND PERCEPTIONS OF SMALL SCALE SUGARCANE GROWERS ABOUT THE MY CANESIM IRRIGATION ADVICE SERVICE:

QUESTIONNAIRE FOR FARMERS AT PONGOLA

Compiled by O Poutaredy and A Singels
Interviews conducted by D Mthembu
November 2006

[Please exclude ~~double strikethrough text~~ and ~~single strikethrough text~~ from all interviews to reduce interview time]

1. GENERAL INFORMATION

1.1. Grower (2 min)

1.1.1. Personal details (optional)

1.1.1.1. Name and surname: ……………………………………………………....
1.1.1.2. Age: ..………………………………………
~~1.1.1.3. Tel: ………………………………………..~~
~~1.1.1.4. Fax: …..……………………………………~~
1.1.1.5. Cell: …………….…………………………

1.1.2. General information

1.1.2.1. What is your highest level of education?…………………..
1.1.2.2. How long have you been a sugarcane grower?…………..
1.1.2.3. Do you use your cell phone to send SMSs? Yes No
~~1.1.2.4. Do you know how to use a computer? Yes No~~
~~1.1.2.5. Do you have access to a computer? Yes No~~
1.1.2.6. Do you have another income except farming? Yes No
1.1.2.7. How much time do you spend to obtain this income?
……..…days/week.

1.1.3. Knowledge about this project

1.1.3.1. How long have been subscribed to the service?………………
1.1.3.2. How many project meetings have you attended in the last 12 months? ……………. …………
1.1.3.3. What is the purpose of the service?

…………………………………………………………………………

..………………………………………………………………………

1.1.3.4. Who is the project leader? …………………………………..
1.1.3.5. What is the name of the computer system/service?
………………………… ……………………………

1.2. Farm (3 min)

1.2.1. Address/locality: Pongola Makhathini
1.2.2. Farm size: ……………ha
1.2.3. Field details:

Area under sugar cane (ha)	Crop start date	Date of harvest	Variety	Row spacing (m)

1.2.4. Farm labour

1.2.4.2. How many people do you use to assist with irrigation? …. ……..
1.2.4.3. Are the field assistants paid Yes No
1.2.4.4. How many hours per week are they employed? …………
1.2.4.5. How often do you interact with them?
Daily Weekly Less frequently
1.2.4.6. Please indicate the involvement of assistants in irrigation management: (1) Assistants receive and interpret SMS advice, or (2) you receive advice, and then to convey an instruction, or (3) you receive advice and move the sprinklers yourself? (1) (2) (3)

1.2.5. Irrigation system of the farm (1min)

1.2.5.1. Area (ha) under different irrigation systems

Flood	
Overhead	
Semi solid	
Solid	
Portable pipe	

1.2.5.2. Sprinkler system proerties
1.2.5.2.1. How many sets of sprinklers do you have? ………..
1.2.5.2.2. How many sprinklers do you have per set? . ...…
1.2.5.2.3. What is the spacing between sprinklers within the line? . ……...m
1.2.5.2.4. What's the spacing between two positions? ..……..m

1.2.5.3. ~~Drip system proporties~~

~~Drip~~	
~~Surface~~	
~~Sub surface~~	

~~1.2.5.3.1. What is the emmitter spacing within the line? ....m~~
~~1.2.5.3.2. What is the spacing between lines? ....…m~~

1.2.6. Irrigation scheduling (5min)

1.2.6.1. How long is your cycle of irrigation in days? ....day(s)
1.2.6.2. ~~Is the irrigation cycle variable/flexible? Yes No~~
1.2.6.3. ~~Do you have control over your pump? Yes No~~
1.2.6.4. How many growers use this pump? ……………
1.2.6.5. Do you think that sharing the pump is a problem? Yes No
1.2.6.6. Please state what indicators you use to stop or start your irrigation

	Yes	No	***[If YES]*** Explain how you do
Soil state			
Rainfall			
State of the plant			
My Canesim advice			
Other……………...			

2. THE USEFULNESS THE SERVICE

2.1. SMS advice content (1 min)

2.1.1. Quantity

2.1.1.1. In your opinion the quantity of information and advice is
Too much Enough Too little

[If the grower answers TOO MUCH]

2.1.1.2. What kind of information do you feel is of little use?

- The grower's name ☐
- The date ☐
- The current yield ☐
- The future yield ☐
- Any other (specify):. ………………………..………

[If the grower's answer is TOO LITTLE]

2.1.1.3. What kind information do you feel should be added?
[Suggest to the grower the important themes in bold if he chooses the important themes propose the details]

Weather information		**<u>Crop information</u>**	
Temperature	☐	Evapotranspiration	☐
Rain	☐	Canopy cover	☐
Relative humidity	☐	Stress days	☐
Wind	☐	RV % cane	☐
Solar radiation	☐		
Soil information			
Soil water content	☐		

2.1.2. Frequency of the advice

2.1.2.1. How frequently have you received advice?
Too frequent OK Too infrequent

[If not OK]

2.1.2.2. What frequency do you prefer to receive your advice?

- Once a day ☐
- Once a week ☐
- Twice a week ☐
- Once a month ☐
- Only when a change in scheduling is needed ☐
- Other (specify)………………………………….…

2.1.3. Means of communication

2.1.3.1. Do you think that there are other means to communicate this advice?

Yes No

2.1.3.2. Please indicate your preference by ranking the options of receiving advice

[1 - most preferred, 6 - least preferred]

Voice mail	
Fax	
SMS	
Email	
Personal interaction with extension officer	
Face to face	
By phone call	

2.2. Adoption and acceptance of advice by growers (2 min)

[For all question relating to frequency, the following guidelines apply: Always – Between 100% and 80%; Most of the time – Between 80% and 40%; Rarely – Between 40% and 20%; Never – Between 20% and 0%]

2.2.1. Clarity of content

2.2.1.1. Do you understand the advice?

Always Most of the time Rarely Never

2.2.1.2. When you do not understand the advice what is your main difficulty?

…………………………………………………………………………….

…………………………………………………………………………….

2.2.2. Acceptance

2.2.2.1. How often do you agree with the advice?

Always Most of the time Rarely Never

[If the grower's answers are RARELY or NEVER]

2.2.2.2. What were the reasons for your non-acceptance?

…………………………………………………………………………………

…………………………………………………………………………………

2.2.3. Implementation

2.2.3.1. How often have you implemented the advice?

Always Most of the time Rarely Never

[If the grower's answer is RARELY or NEVER]

2.2.3.2. What were the reasons for not implementing the advice?

When the advice was to "irrigate" and you didn't irrigate.

No water ☐
Pump breakdown ☐
No time or labour to move the sprinklers. ☐
Problems with your irrigation system. (Line; sprinkler) ☐
The state of soil and plant indicated that it was not necessary to irrigate ☐
Other reasons…………………………………………………… (Specify).

When the advice was to "do not irrigate" and you irrigated

Washing in fertilizer or herbicide ☐
Watering transplants in gaps ☐
The state of soil and plant indicated a need for irrigation ☐
Other reasons…………………………………………………… (Specify)

2.2.3.3. When do you act on the advice you have received?
The same day ☐
The following day ☐
More than one day after receiving the advice ☐

2.2.3.4. If you wait longer longer than one day to react, why?
…………………………………………………………………………………
…………………………………………………………………………………

2.3. Relevance of the advice (2 min)

~~2.3.1. In your opinion, when the advice states that you can stop the irrigation, it generally was:~~
~~Too early A good time Too late~~
~~2.3.2. In your opinion, when the advice states that you resume irrigation, it generally was~~
~~Too early A good time Too late~~
~~2.3.3. If the advice was unsuitable, why?~~
~~…………………………………………………………………………………~~
~~…………………………………………………………………………………~~
~~2.3.4. When it rained enough, the advice suggested that you stop the irrigation:~~
~~Always Most of the time Rarely Never~~
~~2.3.5. In your opinion, is the advice suitable for the irrigation system?~~
~~Yes No~~
~~2.3.6. If the answer is ***NO*** explain why?~~
~~…………………………………………………………………………………~~
~~…………………………………………………………………………………~~

~~2.3.7. Have you followed the drying off advice? Yes No~~
~~2.3.8. In your opinion iwas the advised drying off period ?~~
~~Too short Just right Too long~~

~~2.3.9. ***[If the answer is NOT ENOUGH]*** Why is the dry off advice not suitable for your field?~~
~~…………………………………………………………………………………~~
~~…………………………………………………………………………………~~

2.3.10. Do you have any suggestions to impove the relevance of the advice?
…………………………………………………………………………………

3. RELIABILITY OF THE SERVICE

[The following questions concern the service. These questions are necessary to improve this service]

3.1. System inputs (30 sec)

3.1.1. Did anybody check with you the correctness of the input parameters? (Show a list of parameters from the My Canesim Field Report – Tam, Variety, row spacing, crop start date, harvest date, irrigation systems, Irrigation amount and irrigation cycle)

3.1.2. Did the values accurately represent your situation?

3.1.3. If not, please list the incorrect parameters and indicate whether these were corrected subsequently?

……………………………………………………………………………………….

……………………………………………………………………………………….

[Interviewer – Please confirm the approximate date of the first advice received – this is regarded as the starting date of subscription. The following questions apply to the period after that]

3.2. Grower's trust (30 sec)

3.2.1. Was the service available when you needed it?

Always Most of the time Rarely Never

3.2.2. Do you trust the advice that is given?

Always Most of the time Rarely Never

3.3. Receipt of confirmation SMS (30 sec)

3.3.1. How often have you received the confirmation SMS sent on Wednesdays?

Always Most of the time Rarely Never

3.3.2. How often have you received advice on any other day than Wednesday in the last 12 months?

Weekly	
Every 2nd week	
Monthly	
Once a year	
Never	

3.4. Interaction with the extension officer, SASRI technical staff, Illovo representative (2 min)

3.4.1. How often did each person visit you in the last 12 months?

	EO	SASRI	Illovo
Weekly			
Every 2nd week			
Monthly			
Once a year			
Never			

Subject of discussion

	EO	SASRI	Illovo
Was the My Canesim advice explained in relation to the situation in your field			
Was the field input or output for your field discussed (eg harvest dates, TAM , yields, etc.?			
Was the measurements made on your field explained and discussed with you			
Apart from irrigation matters, what other subjects were discussed?			

3.4.2. How often do you want your extension officer to visit you?

Weekly	
Every 2nd week	
Monthly	
Once a year	
Never	

4. IMPACT OF THE SERVICE

[This part concerns the impact of this advice.]

4.1. Impact on farming practice (2 min)

4.1.1. Have you changed your irrigation scheduling because of the advice you received or from what you have learnt from your participation of this project? Yes No

4.1.2. If yes. please explain how you decide to stop and start irrigation?
……………………………………………………………………………………………

~~4.1.3. Have you changed the way that you dry off your sugarcane due to the advice and /or explanations from project teams members? Yes No~~

~~4.1.4. If yes, please explain how :~~
~~…………………………………………………………………………………………~~
~~…………………………………………………………………………………………~~

4.2. The benefit (5 min)

Indicate in the table below what impact the service had on the different parameters by comparing the status before and after the service delivery)

	*How much impact? (1-5)**	~~Quantity before 2003~~	~~Quantity in 2006~~	~~*Value of the impact (R)*~~
4.2.1. Electricity account (kW/year)				
4.2.2. Water use (m3/year)				
4.2.3. Cane yield (t/ha)				
4.2.4. RV % cane (%)				
4.2.5. Fertilizer (t/ha)				
4.2.6. Labour (mandays/year)				

* 1 - increased significantly, 2 - increased somewhat, 3 - unchanged, 4 - reduced somewhat, 5 - reduced significantly

4.3. Paying for the advice (5 min)

4.3.1. In your opinion, how much is the benefit from the service worth? Please select an option

R 0 ☐ R0-10 ☐ R11-50 ☐ R51-100 ☐ R101-500 ☐ More 500 ☐

4.3.2. Are you prepared to contribute to the cost of providing this service?

	Yes	No
Flat rate	☐	☐
Percentage of the cost saving	☐	☐

4.3.3. What is maximum amount that you are prepared to pay for this service (R/ha/year)? ………………………………….

[If the answer is FLAT RATE] Please select an option

R 0 ☐ R0-10 ☐ R11-50 ☐ R51-100 ☐ R101-500 ☐ More 500 ☐

[If the answer is PERCENTAGE OF SAVING] Please select an option

0% ☐ 10% ☐ 20% ☐ 30% ☐ 40% ☐ 50% ☐

5. OTHER (5 MIN)

[This first part permits to know if this advice changed your farming way or no.]

5.1. Have you learnt about irrigation cane farming for this advice? Yes No

5.2. ***[If the reply is YES]***. What have you learnt about irrigation cane farming from the advice?

……………………………………………………………………………………………

……………………………………………………………………………………………

5.3. Do you think it would be useful to receive other types of famring advice by SMS? Yes No

5.4. What kind of information do you wish to be sent to you by SMS

……………………………………………………………………………………………

……………………………………………………………………………………………

5.5. Have you discussed about this service with other growers? Yes No

~~5.6. If yes, were they interested in this service? Yes No~~

~~5.7. Have they contacted the extention officer? Yes No~~

~~5.8 What are their main difficulties to receive the sercice?~~

~~They haven't the cell phone~~ ☐

~~Their irrigation cycle are non suitable~~ ☐

~~They doubt the efficiency of the advice~~ ☐

~~Their farm is too large~~ ☐

~~Other reasons (specify)……………………………………………………..~~

~~I do not know~~ ☐

11.6. Economic feasibility study report

FEASIBILITY OF PROVIDING REAL-TIME IRRIGATION ADVICE WITH MYCANESIM TO SMALL-SCALE AND COMMERCIAL SUGARCANE FARMERS

BY

PJ FOURIE AND B GROVÉ

Feasibility of providing real-time irrigation advice with MyCanesim to small-scale and commercial sugarcane farmers

By

PJ Fourie and B Grové

Department of Agricultural Economics

University of the Free State

Bloemfontein

February 2008

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1. OBJECTIVES

The overall goal of this project is to evaluate the financial feasibility of using the MyCanesim sugarcane crop information system to provide irrigation scheduling advice to commercial and emerging sugarcane farmers in South Africa. The service consists of real-time advice, delivered when required, either by SMS text messages (to small-scale growers who mostly have single fields), or by e-mail and fax (to commercial growers with multiple fields) (Singels and Smith, 2006). It also entails field visits by field agents/extension staff to assist in the interpretation and implementation of advice, to obtain field information necessary for accurate simulations (Singels, 2007) and in some cases to install and maintain electronic equipment for recording rainfall and soil water status. Thus, it is envisaged that two types of irrigation advice service will be offered, namely irrigation advice alone (backed up with limited field extension), and irrigation advice with field monitoring and limited field extension.

Two implementation options were explored, namely (1) the "irrigation advice only" service provided to Pongola small-scale growers and to commercial growers in the Heatonville/Nkwaleni area, and (2) the irrigation advice with monitoring service to commercial growers in the Heatonville/Nkwaleni area.

Specific objectives are to:

1) Determine the likely changes in cane yield and irrigation water use associated with adopting the irrigation service, and the monetary benefit derived from these changes.
2) Budget the cost of two implementation options to provide the irrigation advisory service to farmers.
3) Determine the net benefit of each implementation option.
4) Quantify the sensitivity of service implementation costs and net benefit to the number of subscribers.

2. DATA AND PROCEDURES

2.1. Quantifying monetary benefits of subscribing to the irrigation advisory service

In order to determine the direct monetary benefit associated with using the irrigation advisory service, changes in the cane yield and water use were used to calculate the impact on gross income and irrigation cost savings. The difference in the resulting gross incomes above specified costs is taken as the monetary benefit of subscribing to service. The procedure that is used to determine cane yield and water use will be discussed first, followed by a short description of the partial budgeting procedure.

2.1.1. Simulated crop yields and irrigation quantities

Three years of data was obtained from SASRI regarding crop yield and water use for Pongola small-scale farmers who utilized three alternative levels of information to determine their irrigation decisions. The first group used SMS advice backed up by infield monitoring (monitor participants), the second group used SMS advice (advice participants) and the last group did not use any of the afore-mentioned. These findings are shown in Table 1. The data show that average cane yields were far below potential, and that cane yield and water use increased as the level of irrigation information used increased.

Table 1 Average yield and seasonal water use for different groups of Pongola small-scale growers

Season:	04/05	05/06	06/07
Crop yield (t/ha)			
All growers with data	99	88	70
Monitor participants	107	92	92
Advice participants	.	90	67
Non-participants	.	83	62
Water use (mm)			
All growers with data	950	783	520
Monitor participants	974	883	700
Advice participants	.	823	450
Non-participants	.	720	.

It was decided not to use actual responses in yield and water use to irrigation advice in the analysis as these variables were severely affected by factors other than irrigation scheduling such as water availability and suboptimal agronomic practices. Missing and unbalanced data also contributed to the difficulty with data interpretation.

In this analysis the potential crop yields and irrigation water use was simulated with the MyCanesim model (Singels, 2007). The model was configured to simulate two irrigation schedules for two soil types, five harvesting months for each year for the period from 1997 to 2007, using the weather record from the Pongola station. The two soil types represent soils with an available water capacity (SWC) of 50mm and 100mm. An irrigation schedule that applies 42 mm every 10 days only when soil water drops below 50% of SWC was used to represent good practice advised by the MyCanesim system (VARIABLE). A fixed schedule that applies 42mm every 10 days regardless of soil water status was used to represent the behaviour of irrigators who do not receive any advice (FIXED).

2.1.2. Partial budgets

A partial budgeting procedure is used to determine the monetary benefits of adopting the irrigation advice service. The only two components that were considered to change when the irrigation farmers adopt the irrigation advisory service were irrigation water use and cane yield, and only costs associated with these were therefore considered. Costs that are affected by changes in cane yield were extracted from enterprise budgets (supplied by S.A. Cane Growers Association) and used to determine the gross income above specified cost for each of the soils and the two irrigation schedules (VARIABLE, FIXED).

Table 2 is a representation of the gross income above specified costs for each of the soil types and irrigation schedules. The gross income above specified costs is calculated as the difference between gross income from cane and the irrigation costs. The higher SWC soil, (SWC=100mm) resulted in higher gross income above specified costs for both irrigation schedules.

Table 2 Average gross incomes above specified costs for two soil types (SWC=50mm, SWC=100mm) and two irrigation schedules (VARIABLE, FIXED).

	Soil water capacity			
	100mm		**50mm**	
	Irrigation schedule		**Irrigation schedule**	
	VARIABLE	**FIXED**	**VARIABLE**	**FIXED**
Cane Yield (t/ha)	122	123	118	119
Irrigation (mm)	929	1554	1010	1554
RV Yield(t/ha)	16	16	16	16
RV Price (R/ton)	1600	1600	1600	1600
Irrigation Cost (R/mm)	2.67	2.67	2.67	2.67
Gross Income (R/ha)	25838	25994	24931	25026
Total Irrigation costs (R/ha)	2479	4146	2694	4146
Gross Income Above Specified Costs (R/ha)	23359	21847	22237	20880

The irrigation costs used in the calculations reflect the water costs associated with scheme operation and statutory levies, electrical power costs for pumping water from the canal to small-scale schemes, as well as the costs for infield pumps and amounts to R2.66/mm.

The difference between the gross incomes above specified costs calculated for the two irrigation schedules was taken as the net benefit that can be derived from subscribing to the irrigation advisory service as apposed to using a fixed irrigation schedule.

2.2. Costs of service implementation options

The costs associated for two service implementation options and three subscription scenarios were provided by SASRI (see Table 3). The first implementation option entails advice with limited extension to commercial as well as small-scale farmers with monthly visits by field agents. The second option entails advice with electronic monitoring for the commercial growers only. Option 2 also includes bi-weekly visits to commercial farmers by field agents. Three different subscription scenarios were analysed with respect to the number of fields, the number of commercial and small-scale farmers and the total area serviced. Important to note is that the total number of subscribers for implementation Option 2 is less than Option 1 because the service only includes commercial farmers. The annual service implementation costs of the implementation options for three subscription scenarios as well as a description of the costs are shown in Table 3. The costs of computers and irrigation equipment were annualised not to over estimate these costs.

Table 3 Annual service implementation costs of two implementation options and three subscription scenarios.

OPTION 1 (Advice with limited extension)				
	Subscription scenario:			
	Level 1	**Level 2**	**Level 3**	
Number of commercial farmers (Heatonville)	10	20	30	
Number of fields per farm	10	10	10	
Number of small scale farmers (Pongola)	50	100	500	
Number of fields per small-scale farmer	1	1	1	
Size of fields (ha)	10	10	10	
Total number fields	150	300	800	
Total area serviced (ha)	1500	3000	8000	
				Description
Human resources				
System administrator/ Programmer	360,000	360,000	360,000	Full package at Paterson C4
Field agents	337,500	675,000	1,800,000	Discuss advice, 8 fields per day, 20 days constitute full time, Paterson C4, based at Empangeni
Operational				
Field agent transport	48,375	96,750	258,000	2000km/month@R2/km, toll – R300/month per agent
Field agent office expenses	45,000	90,000	240,000	Telephone, fax, cell phone, internet, office rent (1/3 rd of extension officer)
Field agent S&T	45,000	90,000	240,000	8 nights a month
Laptop	2,806	5,612	14,964	One per agent, discounted over 3 years
Central office costs				
Web site	24,000	24,000	24,000	
Faxes, SMS, phone calls, photocopies	60,000	60,000	60,000	
Consumables	10,000	20,000	30,000	
Software licenses	30,000	30,000	30,000	
Computer equipment	9,353	9,353	9,353	1 Power PC and one server, discounted over three years
Total Costs	**972,034**	**1,460,714**	**3,066,317**	
Costs Per Hectare	**648**	**487**	**383**	

OPTION 2 (Advice with electronic monitoring)				
	Subscription scenario:			
	Level 1	**Level 2**	**Level 3**	
Number of commercial farmers (Heatonville)	10	20	30	
Number of fields per farm	10	10	10	
Number of small scale farmers (Pongola)	0	0	0	
Number of fields per small-scale farmer	1	1	1	
Size of fields (ha)	10	10	10	
Total number fields	100	200	300	
Total area serviced (ha)	1000	2000	3000	
Human resources				
System administrator/Programmer	360,000	360,000	360,000	Full package at Paterson C4
Field agents	450,000	900,000	1,350,000	Install and maintain monitoring equipment, discuss advice, 8 field per day, Paterson C4, based at Empangeni
Operational				
Field agent transport	94,500	189,000	283,500	3000km/month@R2/km, toll - R300/month
Field agent office expenses	60,000	120,000	180,000	Telephone, fax, cell phone, internet, office rent
Field agent S&T	60,000	120,000	180,000	16 nights a month
Laptop	3,741	7,482	11,223	Discounted over 3 years
Central office costs				
Web site	24,000	24,000	24,000	
Faxes, SMS, phone calls, photocopies	60,000	70,000	80,000	
Consumables	10,000	20,000	30,000	
Software licenses	30,000	30,000	30,000	
Computer equipment	9,353	9,353	9,353	1 Power PC and one server, discounted over three years
Monitoring equipment	142,438	284,876	427,314	Farmers pay once-off fee of R6000 for monitoring station, discounted over 5 years
Spares	10,000	20,000	30,000	To replace broke parts, to be refunded by farmers
Total Costs	**1,314,032**	**2,154,711**	**2,995,390**	
Costs Per Hectare	**1,314**	**1,077**	**998**	

From Table 3 it is clear that Option 1 is less costly than Option 2, mainly because of more frequent visits to commercial farmers and due to the cost of monitoring equipment. Increasing subscription numbers reduces the difference in costs between the two options. The cost of rendering service Option 1 amounts to R648 per hectare (R54 /ha/month) for subscription Level 1. The cost of rendering service Option 2 (advice plus electronic monitoring) amounts to R1314 per ha (R110/ha/month) when subscription Level 1 is considered. As the service is expanded to include more farmers and more hectares under cane, the total cost per hectare decrease significantly for both implementation options.

3. RESULTS

3.1. Cane yield and water use

The monetary benefit to the farmer of using the advisory service is directly linked to changes in water use and cane yield. Figure 1 shows the simulated crop yields and associated water uses over a period of 10 years for the VARIABLE (representing subscription to the advisory service) and FIXED (representing non-subscription) irrigation scenarios. The data are also given in Table 5 and Table 6 in the Appendix.

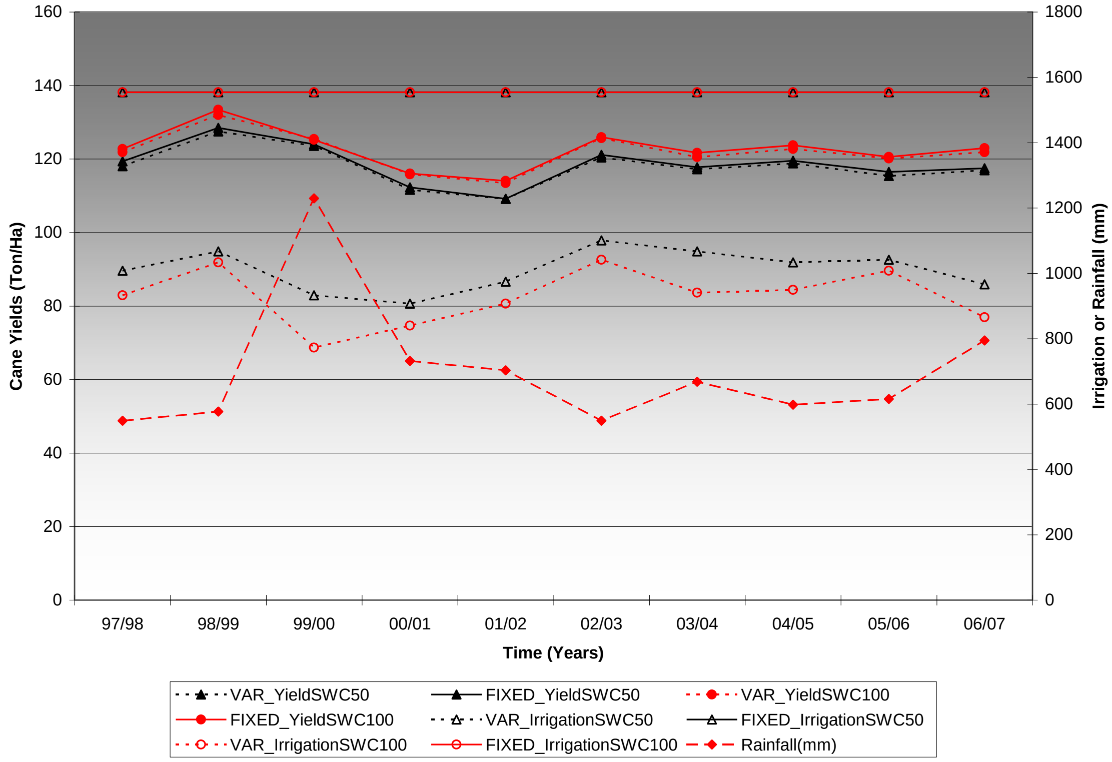

Figure 1 Cane yield and water use over a period of 10 years for two irrigation scenarios (VARIABLE, FIXED) and two soils (SWC=100 mm, SWC=50 mm).

There is almost no difference between simulated cane yields for the two irrigation strategies for a given soil type. The cane yield for the higher SWC soil, however, is higher than that of the lower SWC soil due to the higher buffering capacity of the higher SWC soil. The amount of water applied is vastly different for the two irrigation strategies for a given soil type, and the difference is more for the higher SWC soil than for the lower SWC soil. The FIXED strategy used 35% and 40% more irrigation water than the VARIABLE strategy for the lower SWC soil and higher SWC soil respectively. As can be expected, less water is used when rainfall is high, and the reduction in water use achieved by the VARIABLE strategy increases as rainfall increases. This confirms the importance of accurate scheduling to enable effective use of rainfall.

The conclusion is that changes in applied water will be the most important factor determining monetary benefits, since cane yields did not differ significantly between irrigation scenarios. Reductions in applied water due to scheduling are significantly influenced by soil type and by rainfall. Benefits will ultimately depend on the price of cane and irrigation costs. In the next section the gross income above specified cost for the different irrigation schedules are compared.

3.2. Gross income above specified costs

The gross income above specified costs for the two irrigation schedules and the monetary benefit of adopting the advisory service are shown in Figure 2. The data is given in Table 7 in the Appendix.

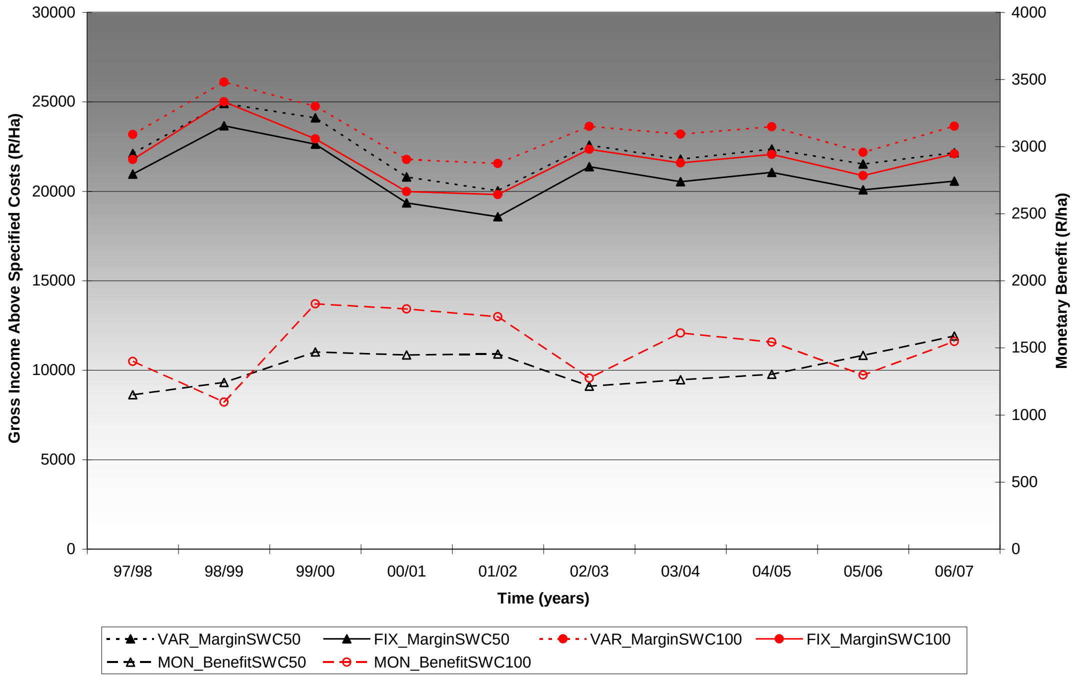

Figure 2 Gross income above specified costs for two irrigation schedules (VARIABLE, FIXED) and the monetary benefit of service subscription for the two soil types (SWC=50 mm, SWC=100 mm).

On average the monetary benefit on the higher SWC soil is R1512 per ha, which is R154 per ha higher than for the lower SWC soil. The monetary benefit on the higher SWC soil ranges from R1588 to R1150 per ha. Monetary benefit is highly positively correlated to rainfall due to increased reduction in water use achieved by the VARIABLE irrigation schedule which represents good irrigation scheduling practices emanating from subscription to the advisory service.

3.3. Net benefit of service subscription

In this section the net benefit to irrigators of subscribing to the service was determined by subtracting the costs of the service from the monetary benefits to subscribers. Implementation costs were calculated for two implementation options and three subscription scenarios (number of subscribers and the area that are serviced). Results are shown in Table 4.

Table 4 Mean net benefit (R/ha) for two service implementation options (Option1: Advice only, Option 2: Advice with field monitoring) with three subscription scenarios (Level1, Level2, Level3).

	Implementation options					
	Option 1: Advice only			Option 2: Advice with field monitoring		
	Subscription scenario			Subscription scenario		
	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Number of Farmers	60	120	530	10	20	30
Number of Fields	150	300	800	100	200	300
Area (ha)	1500	3000	8000	1000	2000	3000
SASRI Costs (R/ha)	648	487	383	1314	1077	998
	Soil Water Capacity: 50mm					
Monetary Benefit	1357	1357	1357	1357	1357	1357
Net Benefit	706	867	971	40	277	356
Benefit/Cost Ratio	**2.09**	**2.78**	**3.54**	**1.03**	**1.26**	**1.36**
	Soil Water Capacity: 100mm					
Monetary Benefit	1512	1512	1512	1512	1512	1512
Net Benefit	855	1017	1120	189	426	505
Benefit/Cost Ratio	**2.32**	**3.09**	**3.92**	**1.14**	**1.40**	**1.51**

The benefit cost ratio (BCR) indicates the benefits for each rand spent. The results in Table 4 shows that service implementation Option1, where no monitoring is done, is highly feasible irrespective of the level of subscription and soil type. All the BCR for implementation Option 1 is greater than two which indicates that the benefits are at least twice as much as the costs of implementing the service. The feasibility of implementation Option 2, where monitoring is done, is doubtful if one considers low levels of subscription to the service. At Level 1 subscription the BCR for the lower SWC soil is 1.03 and 1.14 for the higher SWC soil. These BCR increases to 1.36 and 1.51 for the lower SWC and higher SWC soils respectively when the maximum subscription level is considered. Thus, feasibility of implementation Option2 is highly influenced by the level of subscription.

4. CONCLUSIONS

The main findings of this study were:

The simulated impact of subscription to the advisory service was primarily determined through a reduction in water use and irrigations costs. When subscribed to the irrigation advisory service on average 37% less water is used, resulting in an average decrease in irrigation cost per hectare of R1560. The calculated mean monetary benefit of service subscription was R1512/ha and R1357/ha for the higher SWC and lower SWC soil respectively. The monetary benefit also showed an increase when rainfall increased.

Annual implementation costs decreased from R649/ha to R384/ha for the “advice only” service option, and from R1314/ha to R988/ha for the “advice plus monitoring” service option when subscription to the service increased from the lowest level of subscription to the highest level.

Implementing the advice only service generated high net benefits with BCR above two for all subscription scenarios. Although positive net benefits were derived for all scenarios when the advice plus monitoring option was considered, the feasibility of such an implementation option was highly dependant on the level of subscription to the service. The BCR for the advice plus monitoring option with the highest level of participation were 1.36 and 1.51 respectively for the lower SWC and higher SWC soils.

Care should be taken when interpreting the results since the calculation of monetary benefits to the farmers of using such a service hinges strongly on the assumption that farmers are currently irrigating on a FIXED cycle. Even slight deviations from such a practice may reduce the benefits gained by farmers implementing such a service. The feasibility model (Excel) developed during this study enables a recalculation of benefits for different yield and water use impacts and service costs.

5. REFERENCES

Singels, A. and Smith, M.T. 2006. Provision of irrigation scheduling advice to small - scale sugarcane farmers using a web based crop model and cellular technology: A South African case study. *Irrigation and Drainage 55: 363-372*.

Singels, A. 2007. A new approach to implementing computer-based decision support for sugarcane farmers and extension staff. The case of MyCanesim. *Proc. Int. Soc. Sugar Cane Technol. 26: 211-219.*

6. APPENDIX

Table 5 Simulated cane yields (tons/ha) for two irrigation schedules (VARIABLE, FIXED) and two soil types (SWC=100 mm, SWC=50 mm).

Year	Soil water capacity			
	50mm		100mm	
	Irrigation schedule		Irrigation schedule	
	VARIABLE	FIXED	VARIABLE	FIXED
97/98	118	119	121	122
98/99	127	128	131	13
99/00	123	123	125	125
00/01	111	112	115	116
01/02	109	109	113	114
02/03	120	121	125	125
03/04	117	117	120	121
04/05	118	119	122	123
05/06	115	116	120	120
06/07	116	117	121	122
Mean	117	118	121	122
Min	109	109	113	114
Max	127	128	131	133

Table 6 Simulated irrigation quantities for two irrigation schedules (VARIABLE, FIXED) and two soil types (SWC=100 mm, SWC=50 mm).

Year	Soil water capacity			
	50mm		100mm	
	Irrigation schedule		Irrigation schedule	
	VARIABLE	FIXED	VARIABLE	FIXED
97/98	1008	1554	932	1554
98/99	1066	1554	1033	1554
99/00	932	1554	772	1554
00/01	907	1554	840	1554
01/02	974	1554	907	1554
02/03	1100	1554	1041	1554
03/04	1066	1554	940	1554
04/05	1033	1554	949	1554
05/06	1041	1554	1008	1554
06/07	966	1554	865	1554
Mean	1010	1554	929	1554
Min	907	1554	773	1554
Max	1100	1554	1042	1554

Table 7 Gross annual income above specified costs and monetary benefits for two irrigation schedules (VARIABLE, FIXED) and two soil types (SWC=100 mm, SWC=50 mm).

Year	Gross income above specified costs				Monetary benefit	
	Soil water capacity				Soil water capacity	
	50mm		100mm		50mm	100mm
	Irrigation schedule		Irrigation schedule			
	VARIABLE	FIXED	VARIABLE	FIXED		
97/98	22110	20961	23173	21774	1150	1399
98/99	24904	23662	26101	25006	1242	1095
99/00	24101	22631	24754	22926	1470	1828
00/01	20802	19354	21772	19982	1447	1790
01/02	20031	18577	21554	19822	1454	1732
02/03	22584	21370	23624	22350	1213	1274
03/04	21797	20535	23192	21582	1262	1611
04/05	22360	21057	23605	22062	1303	1543
05/06	21522	20078	22174	20878	1444	1297
06/07	22159	20570	23640	22094	1588	1547
Mean	22237	20880	23359	21847	1357	1512
Min	20031	18577	21554	19822	1150	1095
Max	24904	23662	26101	25006	1588	1828

Table 8 Net Benefits of two implementation options (Advice only, Advice with monitoring) on two soil types (SWC=100mm, SWC=50mm).

	Monetary benefit		Implementation costs			Net benefit					
	Soil water capacity					Soil water capacity					
	50mm	100mm				50mm			100mm		
			Scenario			Scenario			Scenario		
			Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Year	**OPTION 1: Advice only**										
97/98	1150	1399	648	487	383	502	663	766	751	912	1016
98/99	1242	1095	648	487	383	594	755	859	447	608	712
99/00	1470	1828	648	487	383	822	983	1086	1180	1341	1445
00/01	1447	1790	648	487	383	799	960	1064	1142	1303	1407
01/02	1454	1732	648	487	383	806	967	1070	1084	1245	1349
02/03	1213	1274	648	487	383	565	727	830	626	787	891
03/04	1262	1611	648	487	383	614	775	878	963	1124	1227
04/05	1303	1543	648	487	383	655	816	920	895	1056	1160
05/06	1444	1297	648	487	383	796	957	1061	649	810	914
06/07	1588	1547	648	487	383	940	1101	1205	899	1060	1163
Mean	1357	1512	648	487	383	709	870	974	864	1025	1128
Min	1150	1095	648	487	383	502	663	766	447	608	712
Max	1588	1828	648	487	383	940	1101	1205	1180	1341	1445
Year	**OPTION 2: Advice with field monitoring**										
97/98	1150	1399	1314	1077	998	-164	72	151	85	322	401
98/99	1242	1095	1314	1077	998	-72	165	244	-219	18	97
99/00	1470	1828	1314	1077	998	156	392	471	514	751	830
00/01	1447	1790	1314	1077	998	133	370	449	476	713	791
01/02	1454	1732	1314	1077	998	140	376	455	418	655	734
02/03	1213	1274	1314	1077	998	-101	136	215	-40	197	276
03/04	1262	1611	1314	1077	998	-52	184	263	297	533	612
04/05	1303	1543	1314	1077	998	-11	226	305	229	466	545
05/06	1444	1297	1314	1077	998	130	367	446	-17	219	298
06/07	1588	1547	1314	1077	998	274	511	590	233	469	548
Mean	1357	1512	1314	1077	998	43	280	359	198	434	513
Min	1150	1095	1314	1077	998	-164	72	151	-219	18	97
Max	1588	1828	1314	1077	998	274	511	590	514	751	830

11.7. Publications

The following scientific papers and conference papers were presented, published or accepted for publication from the work done in this project.

11.7.1. Scientific publications

- Smith, MT, Singels, A, Neen, J, 2005. Hi-tech irrigation scheduling advice for small-scale sugarcane production. *Proc S Afr Sug Technol Ass.* 79: 225-229.
- Singels, A and Smith, MT, 2006. Provision of irrigation scheduling advice to small-scale sugarcane farmers using a web based crop model and cellular technology: A South African case study. *Irrig and Drain.* 55: 363-372.
- Singels, A 2007. A new approach to implementing computer-based decision support for sugarcane farmers and extension staff. The case of My Canesim. *Proc. Int. Soc. Sugar Cane Technol.* 26: 211-219*.*

11.7.2. Conference papers

- Singels, A 2007. My Canesim: A modern information system for sugarcane farmers, extension and research. Paper presented at the Combined Congress of the SA Crop Production, Soil Science and Horticultural Science Societies held at Badplaas from 23 to 25 January 2007.
- Singels, A, 2008. Real-time irrigation advice for small-scale sugarcane production: A South African implementation case study. 2nd African Regional Congress of the International Committee of Irrigation and Drainage held at the Glenburn Lodge, Johannesburg from 2 to 6 November 2007.
- Singels, A, Kaptein, N and Mthembu, D, 2008. Evaluation of an operational irrigation advisory service to small-scale sugarcane farmers. *Proc S Afr Sug Technol Assoc, 81 (In press).*

11.7.3. Popular media

The following popular articles appeared or were broadcast through popular media during the course of this project:

- SMS saves water in sugar industry by Colleen Dardagan, KZN Industrial & Business News 34, Aug/Sep 2005.
- An SMS for success! Pongola Nuus/News no 337. 7 Oct 2005.
- Tangible success of a joint venture. S.A. Sugar Journal, June 2005.
- Cell phone technology enhances productivity. S.A Sugar Journal, Sep 2005.

- My Canesim meets with small-scale farmers' approval: Update on My Canesim trial. Sugar Journal, Feb 2007.
- Irrigation advice to small-scale farmers. The Link, September 2005.
- My Canesim gets big thumbs-up. S.A. Sugar Journal, March 2008.
- Pongola nuus: Small-scale farmers awarded. 7 March 2008.
- Scheduled irrigation and its challenges by L. Phillips. Farmer's Weekly, 31 March 2008.
- Sweet success with irrigation scheduling. S.A Irrigation 30(3): 16-17, Apr/May 2008, ISBN 0257-5081.
- Ulimo TV programme on SABC2: Several episodes on irrigation scheduling and SMS irrigation advice broadcast in April 2006.

11.8. Capacity building

11.8.1. Farmers

We believe that for most of the farmers involved with the project (47), and in particular the monitor participants (14), the knowledge and skills needed for irrigated sugarcane farming were enhanced by their interaction with researchers, technicians and extension staff.

A demonstration field day was attended by about 130 small-scale farmers from other areas. We believe that this event stimulated the curiosity of farmers from other areas and exposed them to the potential of irrigation scheduling to improve yields, cut costs and improve the profitability of their businesses.

11.8.2. Extension staff

We also believe that the extension officers (R Chiloane, S Zikhali and J Neen) and mill representatives (R Meyer, F Horn and E de Beer) involved learnt a lot about how crop models and weather data could be used to assist them in their job. The few case studies of benchmarking reported here, serve as a model for modern extension methods.

11.8.3. Researchers and technicians

The researchers working on this project (A Singels, M Smith, Y Keleta and A Paraskevopoulos) learnt a lot about the do's and don'ts of participative action research and gained a better understanding of farmer needs and preferences as well as of the practical constraints that needs to be taken into account when developing and implementing technology for agronomic decision support. The feasibility study conducted by Free State University postgraduate student Phillip Fourie and his supervisor Bennie Grove provided an opportunity for learning how to apply theoretical principles and concepts to a real-world situation.

The first SASRI technician employed in this project, Sifiso Myeni, collected data from participating farmers from April 2005 to February 2006, but was dismissed following a disciplinary hearing. During his tenure he has registered for the Masters Degree in Sustainable Agriculture at UFS, attended all lectures in the first year, and successfully completed six assignments. Hopefully he has learnt something from this experience.

On 6 May 2007, the WRC has agreed to provide additional funds to build research capacity of SASRI technicians Nkosinathi Kaptein and Dumisile Mthembu. Kaptein has registered with UNISA for a B.Sc. in Agricultural Science. In 2007 he completed 31 assignments and modules successfully and passed nine subjects (eight with distinction). He has registered for another 14 subjects in 2008 and is due to complete his degree by 2009. Mthembu, a daughter of a participating Pongola small-scale farmer, has registered with the University of South Africa (UNISA) for the National Diploma in Agricultural management. In 2007, she completed 11 assignments successfully and passed three of the four subjects (two with distinction). She has registered for five subjects in 2008. She is due to complete her diploma in 2010.

Kaptein and Mthembu have learnt to interact with farmers, to measure key crop parameters, and to capture, check, process and interpret crop and farmer data. Their extent of learning and capacity building is demonstrated by the fact that they co-authored a short communication that was accepted for the 2008 Congress of South African Sugar Technologists' Association. (Singels, A, Kaptein, N and Mthembu, D, 2008. Evaluation of an operational irrigation advisory service to small-scale sugarcane farmers).

Both technicians have been appointed in new permanent posts as research technicians with ICFR (Kaptein) and as field assistant with SASRI (Mthembu). In both cases, their employers will fund their studies from 2009 onwards. They are now well established to pursue careers in agricultural research.