Tools for Improving Water Use Efficiency: Irrigation Informatics implemented via SMS

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EXTENDED ABSTRACT

Irrigation accounts for between 60 and 70% of all consumptive water use in Australia. Recent emphasis has been placed on improving the efficiency and performance of irrigation systems for improving water use productivity, therefore ensuring the best use of this limited resource. One way of achieving this is for irrigators to use objective scientific data to schedule their irrigations. In this regard Decision Support Systems (DSS) that model soil, plant and weather conditions and provide both timing and volume advice can be used. A focus of the Cooperative Research Centre for Irrigation Futures' Irrigation Informatics project is achieving DSS use.

Many DSS have been developed to help with irrigation scheduling in Australia such as CSIRO's WaterSense, Destiny and MaizeMan. The biophysical modelling that they use is advanced and can lead to great water use efficiency (WUE) gains, for example due to the use of WaterSense, "cane farmers in the Ord reduced their annual applications of irrigation water to sugarcane from 35 to 40 mega litres per hectare to an average of 21 mega litres per hectare without loss of sugar production" (Sugar Research and Development Corp, 2007)

Despite this, they have seen very poor uptake (Hayman 2004 and Inman-Bamber 2005). Two reasons for this are thought to be that irrigators perceive DSS as difficult to use and that computer-based DSS information is not readily available to an irrigator when it is most needed.

This paper describes the use of the Short Messaging Service (SMS), familiar to most cellular phone users, to deliver biophysical data to irrigators in a format with high end-user utility. The system addresses the two reasons thought to contribute to poor DSS uptake mentioned above by keeping the interface as simple as possible and presenting it on a mobile delivery platform thereby ensuring it can be accessed where and when needed.

The system uses reference crop evapotranspiration (ETo) measurements, along with empirically determined crop coefficients, to model actual crop water use which is delivered to irrigators via SMS. All model calculations are undertaken on a remote server with inputs taken from local weather stations or satellite services thereby minimising the information required from the irrigator.

This paper presents the SMS makeup and presentation, followed by a description of the system architecture to be used for experiments in the 2007/2008 irrigation season. This is followed by the design of experiments for the 2007/2008 irrigation season to test the end-user utility of SMS given in thee parts: 1) An experiment to test DSS communication via SMS against other forms of communication, namely the internet, fax and email, 2) An experiment using a series of SMS formats to test 'facilitative' versus 'directive' modes of decision support, 3) An experiment to gauge the extent to which SMS can be used interactively between the irrigator and a DSS.

Preliminary feedback on many of the ideas presented here was collected from several irrigators and information about how the systems have been modified as a result is given.

Finally this paper suggests future SMS and related mobile computing functions, how SMS communication may be added to existing DSS to enhance their functionality, as well as how SMS fits into a new generation of informatics tools for agricultural DSS.

1. INTRODUCTION

Recent emphasis has been placed on improving the efficiency and performance of irrigation systems for improving water use productivity, therefore ensuring the best use of Australia's limited resource that is water. Decision support systems (DSS) that model soil, plant and weather conditions can be used to calculate when an irrigator should next irrigate, based on objective assessments of crop water requirements, and it is thought that if DSS-derived irrigation schedules were followed, water savings could be achieved though efficiency gains.

Australian Bureau of Statistics data indicates that, as of 2003, only one in five irrigators undertook *any* form of objective decision making (Montagu et. al 2006). Additionally, although there are no direct statistics available on the usage of irrigation DSS, numbers are known to be very low with the most popular DSS, such as the APSIM-derived YieldProphet, only seeing usage in the order of a few hundreds (Inman-Bamber 2005). Knowing these figures, the authors' assessment of the problems facing agricultural decision support in Australia is that the greatest are the poor rates of objective decision making and poor DSS uptake. Due to these problems, minimal water savings are actually realised despite evidence that the usage of objective decision making and DSS may lead to such without a loss in productivity (Sugar Research and Development Corp 2007).

Some of the reasons for the poor uptake of agricultural DSS including irrigation DSS, are related to the perceived difficulty of use and the inability of DSS to present themselves as relevant to a particular user through the deployment of personalised information (Hayman 2004).

The Short Messaging Service (SMS) is a communications service that is currently seeing rapid deployment in many sectors from field worker job scheduling to people using matchmaking 'flirt' services. The medium is appealing to many people due to the facts that it is both close to real-time, widely available and cheap. This availability is underpinned by large area cellular phone coverage and the SMS being supported on virtually all cellular phones. Australian cellular phone ownership is about a phone per adult person (IDC Australia 2005) and a future of increased cellular phone usage in Australia seems certain, based on the number of mobile telecommunications service providers and 3rd party service providers using the platform.

With the roll out of rural area coverage of cellular phone services such as Telstra's NextG and Optus' 3G, we are able to assume that most agriculturalists, such as irrigators, have, or will soon have the ability to use the simplest cellular service, SMS.

SMS has been used to assist in irrigation decision support in South Africa (Singles 2005) but the extent to which SMS may be used interactively for agricultural/irrigation decision support has not been tested and the issue of poor uptake has not been previously addressed through the use of a mobile electronic communication medium.

2. THE SHORT MESSAGING SERVICE

The Short Messaging Service (SMS) available on 2nd and 3rd generation cellular phones allows small packets of textual information to be sent between cellular phones and base stations. Most SMS messages (SMSes) are sent from one phone to another, via a base station, however, SMSes may also be generated singly or in batches by machines other than phones and fed to cellular network base stations for distribution to phones via an SMS 'gateway'. The SMS services described in this paper are generated in this way.

2.1. SMS presentation

An SMS consists of a sender and receiver address (the phone numbers), a sent timestamp, a delivered timestamp and a body of up to 160 ASCII text characters. This limits standard SMS functionality to the sending of a few lines of text. Other forms of SMS are mentioned in section 8, 'Future Work'.

Figure 1. Mobile phone displaying a portion of a typical DSS-generated SMS

Figure 1 depicts an SMS, sent from the DSS described here to a standard mobile phone. This SMS is delivering suggested dripper run times, in minutes.

2.2. Back-end architecture

The SMS scheduling messages described in this paper travel from the authors' server, known as the 'irriGATEWAY' server, to a commercial SMS gateway server, then to a mobile provider's base station and from there on to a user's phone.

Figure 2 shows a basic schema of the authors' DSS architecture.

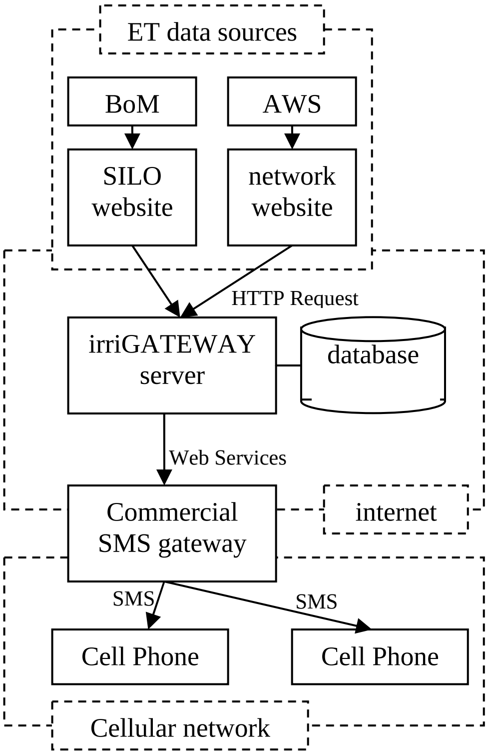

Figure 2. SMS DSS Architecture (BoM is Bureau of Meteorology, AWS is Automatic Weather Station, SILO is a national evapotranspiration (ET) provider service)

The coding for this DSS system was done entirely in Microsoft's C#.NET language (http://msdn2.microsoft.com/en-gb/vcsharp/default.aspx) through the Microsoft Visual Studio.NET 2005 (http://msdn2.microsoft.com/en-gb/vstudio/default.aspx) desktop environment. A Web Services component which facilitates communication between the irriGATEWAY internet server and the commercial SMS gateway, provided by Esendex Pty Ltd, connects internet applications to cellular networks and uses an external interface written by Esendex. This is necessary due to the proprietary nature of cellular networks that deliver SMS. A similar action is required to send facsimiles. This is not required for communication via internet methods, such as web page or email, as those media are inherently handled by internet servers.

The database for the experiments related here is a MySQL (http://www.mysql.com/) 5.0 database. Database management was carried out using the SQLYog utility (http://www.webyog.com/en/).

3. THE DECISION SUPPORT SYSTEM

Evapotranspiration values for a reference crop (ETo) can be used by crop models, in conjunction with empirically determined crop factors (Kc) to generate a particular crop's ET value (ETc) which is then used to determine crop water requirements. Provision of daily ETo or ETc values to irrigators helps them to determine how much irrigation water to apply to their crop and is a well known method for providing decision support (Montagu et al. 2006).

If ET values specific to an irrigator's location can be used in providing decision support to that irrigator, a measure of personalisation can be achieved. Currently there are two ways of sourcing ET values for specific locations in Australia: 1. the SILO meteorological service (http://www.bom.gov.au/silo/), which interpolates ET values from the Australian Bureau of Meteorology across all of Australia, and 2. automatic weather stations (AWS) in various locations which measure variables needed to calculate ET locally.

In its basic mode, decision support to irrigators via SMS described here consists of collecting ETo values from either SILO or AWS networks and sending them out to irrigators on a daily basis, with daily and cumulative values up to a week. In the next, more advanced mode of decision support, daily ETc values for specific crops are supplied to irrigators. The most advanced mode caters for farms using drip irrigation in which dripper run times, based on ETc values and the water delivery specifications of the drip irrigation system, are presented to an irrigator.

3.1. Models

The model used by the DSS to generate decision support values, other than the simple ETo values, is an ET/rainfall/irrigation water balance. In its non-interactive mode, the model simply sums ETc values and rainfall events (expressed negatively) to determine daily crop water requirements. In this mode, no reference is made to irrigation events as the system has no way of learning of them. The daily crop water requirement is presented to irrigators as a cumulative millimetre value for the previous 1 to 7 days. A zero value is presented if negative to relate 'no need for irrigation'. The system's cumulative water balance is presented only for the last 7 days as it is the authors' understanding that irrigators in the initial experiment locality will irrigate at daily to weekly intervals and thus reset their water balance to zero in that time.

In interactive mode, the model receives irrigation events from irrigators via SMS and calculates a continuous cumulative ET/rainfall/irrigation water balance for the whole season.

The drip irrigation system run times for the most advanced form of decision support are generated as detailed in calculations below.

3.2. Data, calculations and values

The ETo data used for the current trial (described below) are taken from SILO and are generated using the Penman-Montieth ET algorithm, as are the ETo data proposed to be used in South Australia from AWS.

The ETo data used for the trials in Griffith region, taken from AWS, are generated using the Penman-Meyer equation.

ETc is determined using $ET_c = K_c ET_o$.

Dripper run times are calculated by knowing the amount of water that is required from the water balance and knowledge of the irrigation system output rate which needs to be provided by the irrigator.

The purpose of calculating dripper run times is that instead of presenting crop water requirements to an irrigator, expressed in millimetres, the DSS is able to present irrigation system run times which is how irrigation systems are operated in practice.

4. SMS EXPERIMENTS

Three experiments and one pilot trial are detailed here. The current trial (4.1) is the first implementation of ET-via-SMS and was started in March, 2007, in conjunction with University of Southern Queensland and Qld Department of Natural Resources and Water. The three experiments (4.2, 4.3 and 4.4) are scheduled for the South East Australian 2007/2008 irrigation season starting in approximately September 2007 and running until March 2008. They are to be conducted in parallel in the Murrumbidgee Irrigation Area. Initially 10 to 15 irrigators growing vines with surface drip irrigation only will be used. Irrigators will be engaged through an initial meeting arranged with the Murrumbidgee Horticulture Council during which instructions for use will be given as well as an information brochure detailing how to measure their drip system's application capacity. Rain gauges & measuring cylinders to be used to measure local rainfall and the growers' system capacity will also be given. Informal meeting will then be conducted with individual growers by the authors to assess their initial understanding and initial use of the system.

During the season, the authors will test the accuracy of the simple water balance model by comparing it to scheduling information generated by running the CSIRO's comprehensive soil-water balance model WaterSense (Inman-Bamber et al. 2004). Some results from WaterSense will be presented to growers for comment.

All SMS interactions will be recorded throughout the season followed up with post season debriefings to determine whether or not growers used the system to guide irrigations. Holding post season debriefings with each irrigator, with all the irrigations, rainfall, ETc and ETo data available, will determine whether the DSS provided benefit in improving irrigation scheduling. Overall, this experimentation will reveal if irrigators find value in putting some (minimal) time into communicating with a simple water balance model.

The aim of the pilot trial is to iron out system problems before the 2007/2008 season and also to gauge the perceived utility of ETo values by a group of irrigators.

The overall aim of the three proposed experiments is to test whether a simple water balance DSS may deliver information with high utility to irrigators, utility here being defined as 'the quality of being of practical use'. The objectives of the three experiments are:

- To determine the relative utility of delivery platforms (traditional fax, emerging email, mobile SMS and internet website).
- To determine the utility of 'facilitative' v. 'directive' decision support
- To determine the utility of a minimalist interactive, mobile, DSS

By 'facilitative' decision support the authors mean support that presents data to a decision maker that can be used in making a decision but does not prescribe an action. 'Directive' support does prescribe an action such as "*irrigate for 3 hours on Monday*".

4.1. Current trial

The current trial operates in the basic mode, that of sending daily ETo values. It delivers them to 12 irrigators in South East Queensland with the ETo values taken from the SILO service. The irrigators can then use the values as a reference to determine relative values for irrigation events.

The system has had significant technical problems relating to ETo data access and this has retarded the assessment of the utility of the service. Qualitative feedback from the trial will be forthcoming in early November 2007 therefore not available at the time of writing but system adjustments, made on the basis of this feedback and used to continue the trial into the 2007/2008 irrigation season, will be presented at the MODSIM07 conference.

4.2. SMS v. other communication

The method used to determine the relative utility of delivery platforms will be:

1. Collect ETo values for an area
2. Send the ETo values irrigators in several formats:
    a. Facsimile
    b. Email
    c. Mobile Phone Short Messaging Service (SMS)
    d. Internet web page
3. Evaluate the irrigator's relative receptiveness to the information formats.

This trial should reveal which of the data presentation formats the irrigators find most useful. Irrigators with a range of technical competency and communications devices will be selected but all the irrigators selected will need to be able to access at least two of the communications methods for comparison. This part of the experiment will only be run for the first month of the irrigation season (September, 2007) after which time a survey of the participants will be conducted. After that point, the participants will be moved into the other experiments.

4.3. Facilitative v. directive

The method used to determine the utility of 'facilitative' v. 'directive' decision will be:

1. Collect ETo and rainfall values for an area. Either grower or AWS supplies rain.
2. Send three different pieces of decision support information, in each of the formats used in establishing the first objective, to comparable irrigators in three different groups. The different pieces of information will be:
    a. The previous day's ETo
    b. A calculated water balance value
    c. Dripper run times calculated from the water balance value, and the specifications of the drip system
3. Evaluate the different irrigator's perceived utility of the three different information types

This methodology should reveal which form of decision support - from 'facilitative' to 'directive' - is preferred by irrigators. It will run for the entire irrigation season with irrigator surveys after 2 weeks, 1.5 months and the full season.

4.4. Extent of interactivity

The method used to determine the utility of a minimalist interactive, mobile, DSS will be:

1. Collect ETo and rainfall values for an area
2. Calculate a water balance for each irrigation unit using ETo, either local rainfall or rainfall notifications provided by the irrigator and notifications of irrigation events sent in by the irrigator
3. Send dripper run times, based on the water balance to irrigators
4. Evaluate the different irrigator's perceived utility of the decision support

This methodology requires irrigators to initiate their SMS service with the irriGATEWAY server. This is done by a 'start service' SMS that contains the dripper system's emitter spacing, row spacing, and application rate. This is then followed by an acknowledgement SMS from the irriGATEWAY server after which confirmation SMS from the irrigator is required.

To facilitate this process, the authors have developed a brochure detailing the steps that are required to be undertaken by an irrigator to measure their drip system delivery rate. The brochure is delivered to the irrigator in a measuring vial, shown in Figure 3, which can be used for the application rate calculation.

Figure 3. SMS service brochure in measuring vial

By undertaking the processes outlined in the brochure, an irrigator not only initiates the SMS service but also learns about their dripper system application rate variability.

Once the service is running, irrigators are required to send their irrigation event values to the DSS on the same or following day. They may also choose to send in readings from their rain gauges. If they do so, their values are used in preference to the database values.

The format of these feedback SMSes are designed to be simple and very short to minimise the effort required to send them. A typical notification of an irrigation event consisting of just two values: the letter 'i' and a numeral which represents the dripper system run time in minutes. The identity of the irrigator is known by the sending phone number and the 'i' tells the system this is an irrigation event as opposed to some other reading. The timing of the event is known to the system as SMS are delivered in close-to-real-time. In the case of rainfall, an 'r' is sent to the system followed by a rainfall reading in mm, again this must be on the same or following day.

5. FURTHER EXPERIMENTATION

It is intended that the qualitative feedback results from the irrigators will be used to improve the system for a renewed round of experiments in the 2008/2009 irrigation season. By locating the entire DSS on a server and not requiring irrigators to store and use any local software, the water balance model may be tuned to present better decision support without the irrigator's involvement.

The same DSS base will be used for the proposed further experiments in 'Future Work'.

6. PRELIMINARY FEEDBACK

Some feedback on the viability of the systems to be tested over the 07/08 irrigation season has already been garnered from several irrigators in the NSW Riverina who will not take part in the experiment. This feedback led to:

1. The possibility for irrigators to use either their own rainfall measurements in the interactivity experiment or those of a local weather station.
2. The ability for irrigators to run the systems here for multiple irrigation management units. This was achieved by allowing irrigators to prefix the values of their irrigation and rainfall event notifications sent to the DSS via SMS with a letter, or number, to signify the appropriate IMU. An example would be that of an irrigator irrigating their IMU labelled 'd' for 230 minutes sends an SMS reading: '`i d 230`' to the DSS. A 13 mm rainfall event on IMU '6' would be expressed as '`r 6 13`'. The decision support for irrigators with multiple IMUs would be presented in a similar fashion so that an irrigator with 3 IMUs, A, B and C, would receive the text in Figure 4.
3. The choice of daily SMS delivery time being by each irrigator, rather than one fixed time.

```
irriGATEWAY
------------------
Dripper run times
for
Y'day: A-250,
B-330, C-270.
2 days: A-510,
B-620, C-545.
3 days: A-790,
B-920, C-770.
```

Figure 4. Text for an SMS sent to an irrigator with multiple IMUs

NOTE: the SMS in Figure 4 uses 154 ASCII characters, as both whitespace and linebreak characters are counted, as opposed to the visible 100 ASCII characters and is close to the maximum length for SMS.

7. CONCLUSIONS

SMS offers the DSS designer the possibility of providing simple, real-time and mobile decision support to agriculturalists. The abilities of SMS to be used as both a non-interactive and an interactive DSS platform have not before been tested and this is the focus of the systems and experiments outlined here. An initial system design and experimental regime to test some aspects of SMS use have been presented.

8. FUTURE WORK

The authors believe that there is scope for further irrigation decision support via SMS. Currently only a water balance has been used to provide decision support and no reference has been made to advanced crop modelling. Once the utility of the basic model's decision support is known, more comprehensive crop models may be tested. Currently it is not known whether a more comprehensive model will add value to the decision support as the utility bottleneck may exist elsewhere such as with user uptake of any form of SMS DSS.

There may be the possibility of adding SMS functionality to existing or new non-SMS-based DSS. An example that can be imagined would be the use of SMS by a platform such as the CSIRO's WaterSense. Figure 5 shows a water balance graph mock-up, similar to those seen in programs like WaterSense, with SMS sending times indicated. In this way a DSS with a graphical interface may use SMS to alert DSS users to particular events, such as when modelled soil water levels reach a certain level. This could compliment the current DSS's functions.

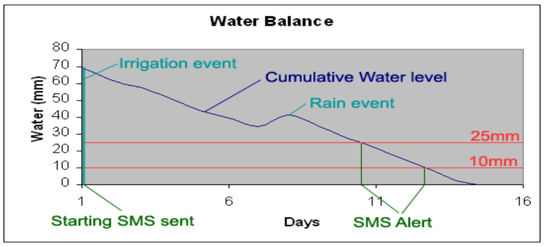

Figure 5. A Mock-up of a water balance DSS graph with SMS sending times when water levels in a soil profile reach a user defined critical level.

Future DSS delivery mechanisms based on the increased interoperability between mobile and internet applications may be envisaged.

The authors also believe there is enormous scope for the use of the SMS-related Multimedia Messaging Services (MMS). An MMS is actually an SMS with additional metadata which allows a web-enabled phone to use the MMS as a hyperlink to navigate to a web page. Such pages, if specifically designed for mobile devices, present the DSS designer with a range of possibilities, such as presenting graphs like that in Figure 5, to an irrigator in the field.

A DSS could use an MMS service to alert a user to modelled events in close to real-time, in the same way as it is suggested WaterSense might use SMS, but with the possibility of the MMS connecting the user to an internet-style DSS interface or additionally spatial information. An example of a web page formatted for mobile devices that presents the last 7 day's ETo values for Griffith, NSW, is given at http://irrigateway.net/dev/mobile/MobPlot.aspx. This page can be viewed on both mobile and non-bile devices and may be connected to via MMS.

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