LARGE SCALE, LOW COST IRRIGATION SCHEDULING – MAKING USE OF SATELLITE AND ET_0 WEATHER STATION INFORMATION

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ABSTRACT

Irrigation scheduling is an important aspect in maximising yields and improving water use efficiency but many irrigators still do not utilise quantitative tools for irrigation scheduling. This is due to a number of reasons related to cost and ease of use of equipment along with social aspects. At the last census only 20% of growers used some form of soil moisture monitoring device for irrigation scheduling with many still relying on ‘gut feel’ or non-quantitative measures.

This paper outlines an irrigation scheduling approach using the reference evaporation (from weather stations) with crop coefficient approach which has existed for the past 30 years and shown to be robust scientifically, but has been difficult to apply practically. While weather station determinations of reference evapotranspiration (ET_0) are practical and easy to access in most irrigated regions, the difficultly has been in determining localised crop coefficient (K_c) information. Crop coefficients are affected by management (irrigation, fertiliser etc), soil type and varietal differences and often show variation even within crops in the same region due to these factors. This has proven a major limitation to applying a reference evaporation with crop coefficient approach for providing practical scheduling information on a per paddock basis.

Recent advances in remote sensing have seen the use of visible and near infrared light wavelengths used for determining vegetation indexes. These indexes, particularly the Normalised Difference Vegetation Index (NDVI) have the potential to be used for providing site specific crop coefficient information. A number of authors have found linear relationships between NDVI and crop coefficients for a broad range of crops. These relationships allow a practical method which can be used to gain large scale, low cost, site specific crop coefficient information which can then be used with reference evapotranspiration from weather stations to provide paddock specific scheduling information. This crop coefficient derivation process is described in this paper together with a description of a Short Message Service (SMS) used to provide this information through a simple mobile phone text message to irrigators on a daily basis.

INTRODUCTION

As water continues to be the limiting factor in Australian based irrigation systems increased importance is being placed on its management. While this is not a new situation, the tools and techniques for maximising the potential use and productivity of that water have only been adopted slowly at the irrigator level. Current indications are that only approximately about 20% of irrigators use some form of quantitative irrigation scheduling method such as soil moisture monitoring. Limitations of uptake

have included system costs and also the complexity of the data/information provided reducing the useability and practical application for irrigators.
In order to overcome some of these limitations a system has been developed through the CRC for Irrigation Futures which aims to have reduced costs compared to soil moisture monitoring and also to reduce the complexity of information provided to the irrigator. The SMS irrigation scheduling service we have developed uses satellite derived vegetation images to derive crop coefficients, current on-ground weather station networks for reference evapotranspiration (ETo) and the readily available and easily accessible mobile phone SMS system to deliver the irrigation scheduling information. The irrigation scheduling data is delivered to irrigators in a most user friendly format, which are irrigation pump run times to replace the previous day's evapotranspiration. The focus of the system at this stage has been on delivering this irrigation scheduling information for irrigated horticultural crops on pressurised systems.

This paper introduces the general concepts behind the system which has the potential to deliver a user friendly, low cost irrigation scheduling information over large areas, potentially improving irrigation efficiency and creating water savings

SMS IRRIGATION SCHEDULING SERVICE

Figure 1 presents a schematic representation of the SMS Irrigation Scheduling Service showing how the specific components are incorporated into the system.

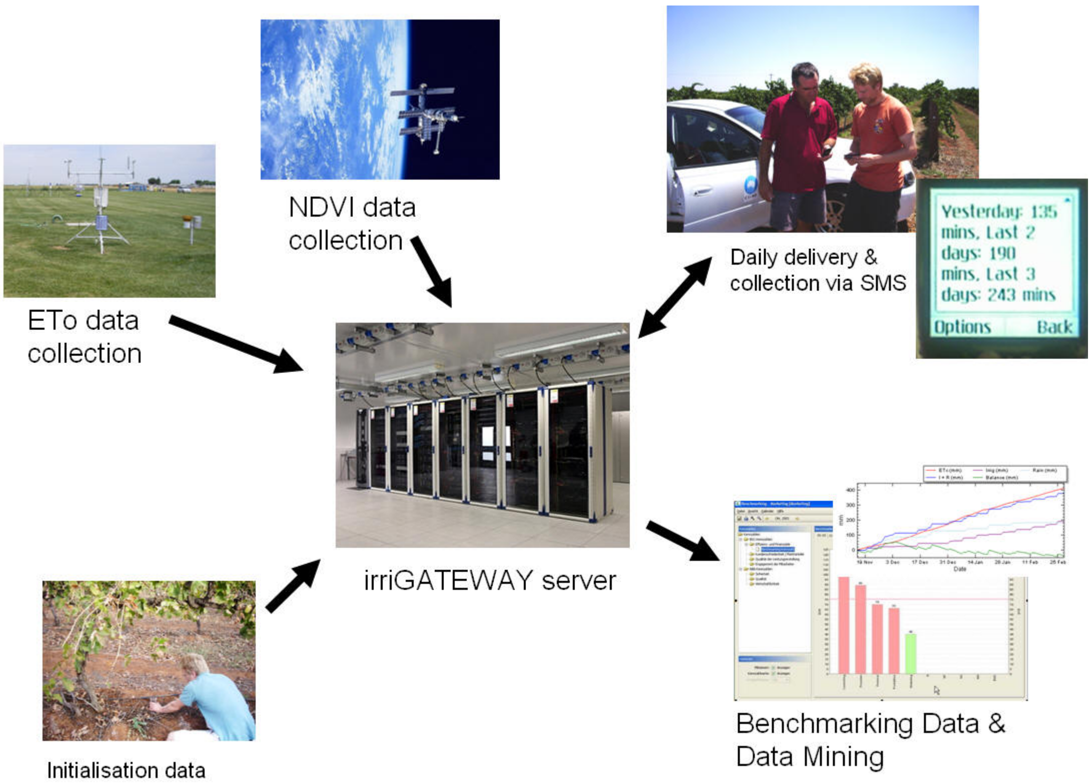


Figure 1 Components of the SMS Irrigation Scheduling Service

This hybrid satellite and SMS system removes all the tedious calculations needed to convert weather station ET_0 data and crop coefficient data to useful decision making information for the irrigator. The system uses the application rate data of the drip irrigation system and provides a simple determination in minutes of how long the drip system should be run to replace the crop evapotranspiration on a daily basis which is then delivered directly to the irrigator through SMS. This provides information to the irrigator where and when he needs it and in a format on which they can make a management decision. Irrigation run times are then sent by SMS back to the irriGATEWAY server and stored for further use as benchmarking data against other irrigators. This can then be presented on a webpage which the irrigator or irrigation water provider can access. See www.irrigateway.net/tools/sms.aspx . Specific components and functions of the system are described in the following sections.

irriGATEWAY server and Scheduling Approach

At the centre of the system is the irriGATEWAY server which acts as a data collection portal for the various data feeds and a calculation engine to convert these data into useable irrigation scheduling information. The use of weather station information in irrigation scheduling has long been used in the scientific domain for predicting crop water requirements and scheduling irrigations (Allen et al. 1998). The general approach that is widely accepted is given in Allen et al. (1998) and is based on the application of reference station evapotranspiration figures which are collected over a grass reference surface (ET_0). This reference evapotranspiration is used to represent the climatic conditions under which evapotranspiration takes place, which is then used to calculate actual evapotranspiration (ET_c) for specific crops by multiplying the ET_0 by a specific crop coefficient (K_c). Generally four K_c values are used over the growing season, - initial, mid, full and late. The crop coefficient takes into account differences in canopy cover, stomatal characteristics, aerodynamic properties and albedo, which affect the rate at which crops evapotranspire compared to the reference crop ET_0. Therefore ET_c for a specific crop is given by:

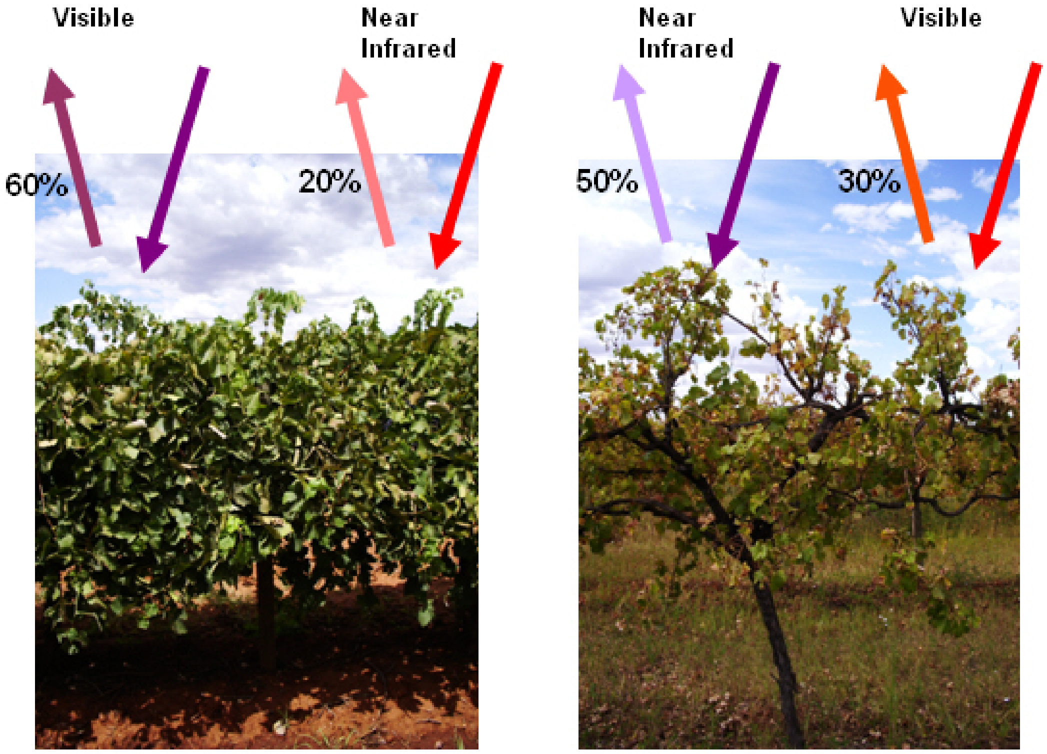
$$ET_c = ET_0 \times K_c$$

A limitation of this approach has been that the crop coefficient (Kc) is specific to a particular crop, irrigation system, soil and management. There have been a number of approaches used to derive crop coefficients which measure actual crop evapotranspiration and compare this to reference evapotranspiration allowing a K_c to be developed for that crop. However, these methods (e.g. eddy covariance, bowen ration, water balance) are expensive and require a high level of expertise to implement. As slight changes in agronomic management, soils and irrigation regimes affect the crop coefficient this makes it difficult to derive a specific crop coefficient for an individual crop. Weather station information for determining reference evapotranspiration (ET_0) is commonly available through nearly all of the irrigation regions in Australia.

The irriGATEWAY server directly sources weather station information and NDVI satellite information which are data feeds provided to the server. It then uses this information for determining actual crop water use for the irrigators specific crop and management situation and runs a basic water balance model. This data is then converted into an actual pump/dripper run time and is sent directly to the irrigator on a daily basis.

NDVI Satellite Data for crop coefficient determination

A number of authors have observed and reported strong correlations between vegetation indexes and canopy cover. Recently, Trout et al. (2008) reported on findings showing strong relationships between satellite derived measurements of Normalised Vegetation Index (NDVI) and crop canopy cover which can be directly related to crop water use in a number of horticultural crops in the San Joaquin Valley in California. The NDVI is an index generally expressed as a ratio between 0-1 of the red and near infrared reflectance by plants. Larger, greener canopies give higher NDVI values than smaller less healthy plant canopies (Figure 2).



$$NDVI = \frac{R_{NIR} - R_{red}}{R_{NIR} + R_{red}} = \frac{0.6 - 0.2}{0.6 + 0.2} = 0.5 \qquad NDVI = \frac{R_{NIR} - R_{red}}{R_{NIR} + R_{red}} = \frac{0.5 - 0.3}{0.5 + 0.3} = 0.25$$

Figure 2 Calculation of NDVI for two irrigated grapevine canopies.

Canopy cover is a direct driver of crop water use and hence allows a direct relationship to be developed between NDVI satellite derived values and crop coefficients which take into consideration specific agronomic and management conditions for individual crops. This allows a specific crop coefficient to be derived on an area as small as 30x30m when data from the Landsat Thematic Mapper satellite is used. Trout and Johnson (2007) provides NDVI:K_c relationships between a number of horticultural crops based on Landsat derived NDVI data and results from lysimeter studies relating canopy cover measurements to crop coefficients. The system detailed in this paper has been largely tested with winegrape producers and relies on NDVI to crop coefficient relationships detailed in Johnson and Scholasch (2005).

REFERENCE EVAPOTRANSPIRATION (ET_0) DATA

ET_0 data for the current system is sourced from local weather stations that provide reference evapotranspiration data on the web. Current system testing has been undertaken in the Murrumbidgee Irrigation Area of NSW, Australia with ET_0 data from the CSIRO Griffith Laboratory weather station www.clw.csiro.au/services/weather . Data is available directly on the internet and can be accessed by end users. Any source of ET_0 data can be used and the system can potentially run using the SILO (Special Information for Land Owners http://www.bom.gov.au/silo) climatic database for areas which do not have reliable, locally measured ground ET_0 information.

INITIALISATION DATA

Characteristics of the irrigators drip irrigation system are collected and used to subscribe to the SMS irrigation scheduling system. A brochure containing information on how to subscribe to the system is contained in a measuring cylinder which is used to collect application rate data from the irrigators system, Figure 3. Initial data on the irrigation system including application rate, plant and row spacing is sent through a text message to the irriGATEWAY server which stores this information on a database for later use in calculations for determining irrigation times.

Figure 3 Brochure containing sign up information and measuring vial for determining dripper application rates.

BENCHMARKING AND DATA MINING

Irrigation run times from irrigators are sent back by SMS to the irriGATEWAY server which stores this information in a database for use in benchmarking activities. Real-time information is then available to irrigators in an anonymous fashion from the irriGATEWAY website www.irrigateway.net/tools/sms.aspx which allows individual irrigators to compare their water use profiles on a ML/ha basis, as calculated from their actual irrigation application rate and run time, with other users or for water providers to access trends in water use statistics.

DATA DELIVERY AND COLLECTION VIA SMS

The system relies on an SMS interface for communicating with irrigators (Car et al. 2007). The system has the ability to collect information from SMS messages that are sent to it via an SMS gateway service provided by Esendex Pty. Ltd (www.esendex.com.au). Presently, incoming SMS messages are related to initialisation data, dripper run times and rainfall amounts.

The irrigation scheduling information is sent to irrigators on a daily basis and consists of suggested dripper run times to replace plant water use for the previous 1-7 days (Figure 4). Conversion to a dripper or pump run time in minutes provides the irrigator with a direct, understandable measure which they can use to base scheduling on. It has also been found that by providing the information in this easily understandable format, to which the irrigator can easily relate, provides maximum utility of the data.

Figure 4 SMS message containing dripper run time information

INITIAL RESULTS

The system has been trialled with a number of winegrape irrigators in the Murrumbidgee Irrigation Area during the 2007/08 irrigation season. The irrigators have received a daily SMS message with irrigation scheduling information in the form of suggested drip irrigation run times. The irrigators are benefiting from the system, to the extent that they are sending back the required irrigation and rainfall data without prompting. Feedback overall has been positive and indications are that irrigators using the system see great potential in its application, due to its low cost and tailored, farm specific information for individual growers. Extensive validation of the system is planned with 60-70 growers during the 2008/09 irrigation season.

SUMMARY

Previous authors have found significant relationships between satellite derived measures of vegetation indexes and crop coefficients. This finding has the potential to provide tailored 'irrigator useful' information for scheduling irrigations. Coupling of the Landsat satellite-derived crop coefficients and the SMS delivery service now offers the potential to provide low cost, personalised (for crop type and management condition) irrigation scheduling information to individual irrigators across an irrigation district. Other benefits also include high spatial resolution of scheduling information (approx. 30mx30m) which allows irrigators to better manage spatial variability to maximise production, minimise costs and environmental impacts, such as deep drainage.

The benefits to the Australian irrigator sector are a potential significant step in providing low cost ($1 a day) personalised, crop specific and management specific irrigation scheduling system with potentially universal coverage, catapulting the remaining 50-70% of irrigators into the benefits of high tech quantifiable irrigation scheduling techniques. The system and framework as developed has the potential to be easily rolled out over numerous crops and regions once this work has been completed.

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REFERENCES

Allen, R.G., Pereira, L.S., Raes, D. & Smith, M. (1998) Crop Evapotranspiration – Guidelines for computing crop water requirements, FAO Irrigation and Drainage Paper 56, http://www.fao.org/docrep/X0490E/X0490E00.htm

Car, N. J., E. W. Christen, Hornbuckle, J.W., Bartlett, C. & Moore, G. (2007). Tools for Improving Water Use Efficiency: Irrigation Informatics implemented via SMS. MODSIM 2007 International Congress on Modelling and Simulation, Wellington, New Zealand, Modelling and Simulation Society of Australia and New Zealand. Online at: http://mssanz.org.au/MODSIM07/papers/11_s57/ToolsForImproving_s57_Car_.pdf

Johnson, L. and Scholasch, T. (2005) Remote Sensing of Shaded Area in Vineyards, HortTechnology, Oct-Dec, 15(4) pp. 859-863

Trout, T.J., and Johnson, L.F. (2007) Estimating crop water use from remotely sensed NDVI, Crop Models and Reference ET, USCID Fourth International Conference on Irrigation and Drainage, The Role of Irrigation and Drainage in a Sustainable Future, Eds. Clemmens, A.J., Anderson, S.S, Sacramento, California, October 3-6, 2007

Trout, T.J., Johnson, L.F. and Gartung, J. (2008) Remote Sensing of Canopy Cover in Horticultural Crops, HortScience 43(2):1-5