IrriSAT – weather based scheduling and benchmarking technology

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Abstract
IrriSAT is a weather based irrigation management and benchmarking technology that uses remote sensing to provide site specific crop water management information across large spatial scales.

Developed in partnership with the CRC for Irrigation Futures, IrriSAT uses satellite imagery to estimate crop coefficients (Kc) at a 30 m resolution. IrriSAT calculates Kc from a linear relationship with satellite derived Normalised Difference Vegetation Index (NDVI). Daily crop water use is determined by simply multiplying Kc and daily reference evapotranspiration (ETo) observations from a nearby weather station. A seven day forecast of ETo is also produced.

A delivery platform is being developed using the Google App Engine. The app will provide easy access to the IrriSAT crop water use data, which coupled with weather and crop water use (ETc) forecasts will enable irrigators to track their soil moisture deficit and better manage irrigation schedules. Spatial crop water use information determined by IrriSAT is also available through the IrriSat app and will allow users to investigate water use difference within and between fields. This information can be used for changing management decisions along with investigating the impacts of these decisions.

Introduction
Irrigation water is scarce, there are competing needs between the environment, urban communities and agricultural uses (Roth et al. 2013). In the Gwydir Valley in Northern NSW, on average irrigators only receive about 30 per cent of their water entitlement (NSW Office of Water 2015). Therefore, maximising on-farm water use efficiency is vital to farm profitability.

Irrigation scheduling matches the timing and volume of irrigation water supplied for crop needs (Wigginton et al. 2012). Of Australian cotton growers, 70 per cent use soil moisture monitoring to assist their irrigation decisions (Roth 2014). This technique often relies on one soil water content profile to represent very variable fields.

Weather based irrigation scheduling estimates crop water use (ETc) as the proportion of reference evapotranspiration (ETo), calculated from climate parameters using a multiplier or crop coefficient (Kc), which varies with the stage of crop growth (Allen et al. 1998), where ETc = ETo x Kc. The weakness in this approach is in estimating the crop coefficient (Trout and Johnson 2007) and often generic Kc curves do not match the actual crop water use. Weather based scheduling techniques have not been widely adopted in the cotton industry due to the problem of determining site specific crop coefficients. Kc is related to crop light interception and canopy cover which can be estimated from remotely sensed observations of the normalised difference vegetation index (NDVI) (Trout and Johnson 2007).

IrriSAT is a weather based irrigation service driven by satellite data to estimate Kc and ETc at the same 30m resolution as the satellite (Hornbuckle et al. 2009). IrriSAT was successfully used in the Murrumbidgee Irrigation Area by grape and citrus irrigators to estimate daily crop water use and provide irrigation scheduling information to growers (Hornbuckle et al. 2009). It was first trialled in the cotton industry by two consultants in the Gwydir Valley in Northern NSW during 2009/10. In 2010/11 it was trialled by ten cotton consultants in Northern NSW over 20,000 ha. In 2011/12 the IrriSAT technology was applied over 75,000 ha. Although developed primarily as an irrigation scheduling tool, IrriSAT data also provide a means of benchmarking crop water productivity at field, farm and regional scales.

Proceedings of the 17th ASA Conference, 20 – 24 September 2015, Hobart, Australia. Web site www.agronomy2015.com.au

The Australian Cotton Research and Development Corporation (CRDC) is funding research by NSW DPI, Deakin University and CSIRO to roll out IrriSAT across the cotton industry as an irrigation scheduling tool and to use the data to benchmark crop productivity for all Australia's cotton growing regions.

IrriSAT

IrriSat integrates two sources of information, satellite imagery (to calculate NDVI) and reference evapotranspiration (ETo from on-ground weather stations) to estimate the crop coefficient (Kc). The crop coefficient is used to adjust the ETo for a specific crop type, where crop height, albedo, canopy resistance and bare soil evaporation is integrated into a single parameter specific to that crop type.

Satellite data and calculations

Normalised Difference Vegetation Index (NDVI) is calculated as the ratio of the difference to the sum of the near infrared reflectance (R_{NIR}) and red reflectance (R_{Red}) and range between 0-1 such that:

$$NDVI= \frac{(R_{NIR}-R_{Red})}{(R_{NIR}+R_{Red})} \qquad \text{Equation 1 (Tucker 1979)}$$

Remote sensing of the crop is undertaken using the Landsat satellite platform. These satellite platforms have been used because they are free and have the spectral, spatial (30m pixels) and temporal (8-16 days) resolutions appropriate for IrriSAT. The best available, cloud free data from the Landsat 7 and 8 satellites is selected. While there are small differences between Landsat 7 and 8 (Dandan and Xulin 2014) the NDVI calculated from both satellites is essentially the same.

Trout and Johnson (2007) found a strong linear relationship between NDVI and crop canopy cover for various crops in semi arid areas of California. Since transpiration is proportional to crop cover it is reasonable to relate the NDVI to a crop coefficient value. This approach allows NDVI values to be converted to a crop coefficient and hence produce a Kc map across the satellite image.

The crop coefficient is calculated from the NDVI by equation 2 which is derived from Trout and Johnson (2007).

$$Kc = 1.37 * NDVI - 0.086 \qquad \text{Equation 2}$$

On ground climate measurements

Reference crop evapotranspiration (ETo) is calculated from observations from a network of automatic weather stations installed across most cotton regions. This data is freely available via the IrriGateway website http://www.irrigateway.net/weatherstations. ETo calculations are based on the ASCE Standard reference evapotranspiration equation as detailed in Allen et al. (2005). CSIRO also provides a seven day ETo forecast. The weather station closest to the field or point of interest is used in these calculations.

Daily crop water use

By combining reference evapotranspiration (ETo) and the Landsat derived crop coefficient (Kc), crop water use (ETc) can be determined on a 30m x 30m basis such that:

$$ET_c= ET_0 \times K_c \qquad \text{Equation 3}$$

Using the forecast ETo data, an estimated crop water use for the next seven days can be calculated. Importantly, daily ETc can be summed to calculate seasonal crop water use. This information can be used for crop productivity benchmarking and also for water budgeting.

IrriSAT app

An app is being developed to deliver ETc and Kc to any web enabled platform including smart phones, tablets and desktops. A beta version of the app is currently available at https://irrisat-cloud.appspot.com/, developed using Google App Engine (GAE). Fields are added as polygons drawn by users who must also input the timing and quantity of irrigation and rainfall to drive a daily water balance model. The IrriSat app will have similar functionality to the US Smartirrigation Cotton app http://smartirrigationapps.org

(Vleeshouwer et al. 2015). Currently the IrriSAT app displays NDVI and Kc as surfaces (Figure 1). Time series of field averages of these data can be calculated and downloaded for further analysis. These data will allow irrigators to make better informed water management decisions.

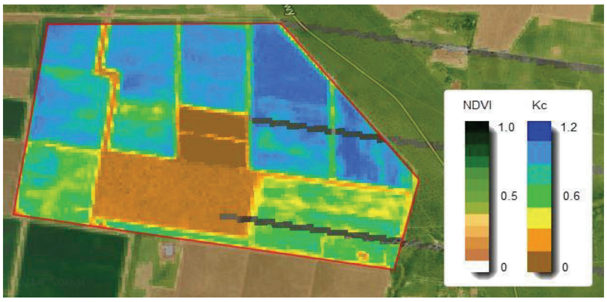

Figure 1: A screen dump of crop coefficients calculated by the IrriSAT Google App

The IrriSAT app will deliver irrigation water management information to irrigators to assist in irrigation scheduling and crop productivity benchmarking.

Benchmarking crop productivity

IrriSAT was used to benchmark around 80 cotton fields in the Gwydir Valley during 2010/11 (Soppe et al. 2012). This initial benchmarking exercise showed that yield increased with water use and that certain practices grouped together (Figure 2). The water use efficiency of the fields studied is indicated by the slope of this plot. However, the deviations from this general trend identify over- and under- performing fields and this holds the key to improving water productivity. For example, a yield of eight bales per ha can be achieved by using between 500 and 650 mm of water. On the other hand, using 600 mm of water can deliver between 7 and 10 bales per hectare of lint. By examining field characteristics and management, the reasons for differences in water use efficiency can be determined.

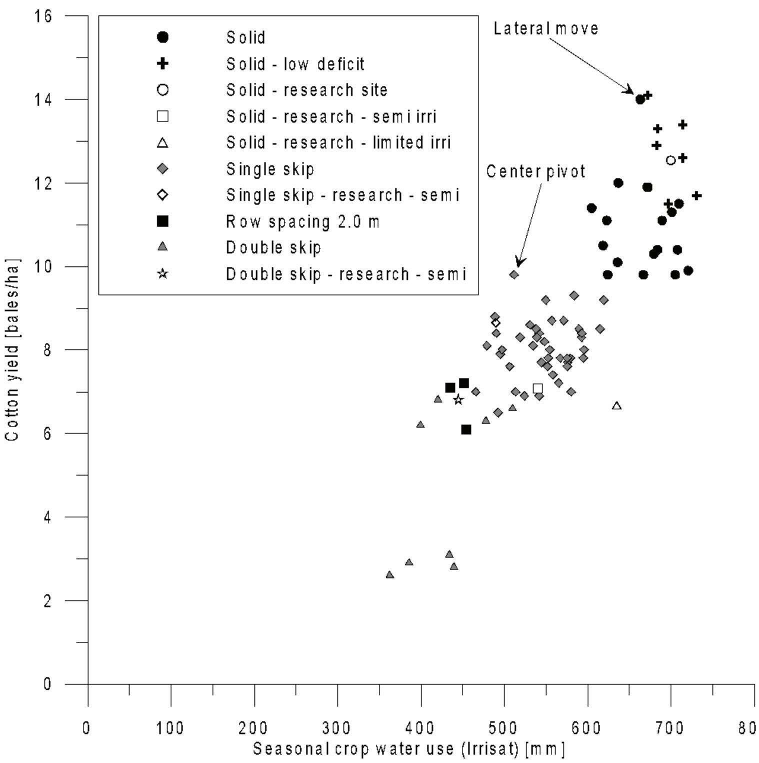

Figure 2: Cotton yield and seasonal crop water use for different row configurations, irrigation systems and water regimes in the Gwydir Valley, NSW for 2010-11 season.

Conclusions

IrriSAT will complement existing irrigation scheduling tools with the advantage of low cost and complete spatial coverage. Preliminary trials of the IrriSAT technology as a benchmarking tool have enabled irrigators to examine variation in crop productivity between fields and farms. Identifying over-and under-performing fields holds the key to improving water productivity.

Key words

Cotton, crop coefficient, irrigation water use efficiency

References

Allen, RG, Walter, IA, Elliot, RL, Howell, TA, Itenfisu, D, Jensen, ME & Snyder, RL 2005, ASCE Standardized Reference Evapotranspiration Equation, American Society of Civil Engineers.

Allen, RG, Pereira, LS, Raes, D & Smith, M 1998, Crop Evapotranpiration Guidelines for computing crop water requirements, FAO Irrigation and Drainage Paper 56, FAO, Rome.

Dandan, X & Xulin, G 2014, Compare NDVI Extracted from Landsat 8 Imagery with that from Landsat 7 Imagery, *American Journal of Remote Sensing*, Vol. 2, No. 2, 2014, pp. 10-14. doi: 10.11648/j.ajrs.20140202.11

Hornbuckle, J, Car, NJ, Christen, EW, Stein TM & Williamson, B 2009, IrriSatSMS Irrigation water management by satellite and SMS – A utilisation framework, CSIRO and CRC for Irrigation Futures, CSIRO Land and Water Science Report No 04/09.

NSW Office of Water 2015, Water allocation reports, NSW historical allocations, WaterInfo, NSW Government. Available from: http://waterinfo.nsw.gov.au/ac/allocation.shtml. [20 April 2015].

Roth, G 2014, Australian Grown Cotton Sustainability Report 2014, Cotton Australia and Cotton Research and Development Corporation.

Roth, G, Harris, G, Gillies, M, Montgomery, J & Wigginton, D 2013, Water-use efficiency and productivity trends in Australian irrigated cotton: a review, *Crop and Pasture Science*, 64, pp. 1033-1048.

Soppe. R, Hornbuckle, J & Montgomery, J 2012, Cotton water productivity in the Gwydir, NSW, paper presented at the Irrigation Australia Limited (IAL) Conference, Adelaide, 22-26 August 2012.

Trout, TJ & Johnson, LF 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.

Tucker CJ 1979, Red and photographic infrared linear combinations for monitoring vegetation, Remote Sensing of Environment, 8, pp. 127-150

Vleeshouwer, J, Car, N & Hornbuckle, J 2014, A cotton grower's decision support system and benchmarking tool using national, regional and local data, paper presented at the ISEE Conference, 25-27 March 2015, Melbourne.

Wigginton, D, Brotherton, E, Smith, B, Roth, G, Gibb, D, & Henggler, S 2012, 'Irrigation Scheduling', in D Wigginton (ed.), *WATERpak*, CRDC, pp 141-159.
http://crdc.com.au/sites/default/files/pdf/Cotton-WATERpak-2013-.pdf