



Final Report

On Farm Series | Cotton Research & Development Corporation

*If you are participating in the presentations this year, please provide a written report and a copy of your final report presentation by 31 October.
If not, please provide a written report by 30 September.*

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: CLW1201

Project Title: Extension of the IrriSAT irrigation management and benchmarking tools into the cotton Industry – Phase II

Project Commencement Date: 1/09/2011 **Project Completion Date:** 30/06/2012

CRDC Program: Farming Systems

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Part 2 – Final Report Executive Summary

IrriSAT is a weather based irrigation water management and benchmarking service that uses satellite imagery to better determine site specific crop coefficients that are needed to accurately calculate crop water use figures. The system uses local weather stations to measure sunlight hours and intensity, cloud cover, rainfall and wind which are all used to calculate a reference crop water use in the past 24 hours. This information when combined with the satellite-determined crop coefficient for a particular crop allows a site specific crop water use figure to be calculated for an individual field.

After initial successful trials using IrriSAT in the Gwydir region during the 2010/2011 irrigation season this project extended and expanded the trial to cover additional cotton growing regions in the Namoi and Walgett areas. During the 2011/2012 irrigation season approximately 80 000 ha of irrigated cotton was monitored with the IrriSAT system over these three cotton growing areas. Issues with non-transmission of satellite data from one of the main NASA satellite sensing systems (Landsat 5) used by IrriSAT limited the trials ability to provide real-time irrigation scheduling information throughout parts of the irrigation season, however the water use and yield benchmarking components of the system were able to be assessed and provided useful information to trial participants which allowed them to assess the performance of their water management strategies and benchmark their performance between fields and also between regions. Strong relationships between yield and IrriSAT determined crop evapotranspiration were found which were consistent across regions, providing confidence that the IrriSAT system has further potential to be used as an initial forecasting tool for predicting yield potential. The results also showed there was a wide variation in water use productivity between fields, growers and regions. This information can then be used for respective strategic analysis of decisions regarding water management.

The IrriSAT system when adopted widely across the cotton industry will place the industry in a unique position at the forefront of water management technologies. The IrriSAT system provides water management information over large areas at low cost to improve water use productivity. The IrriSAT system also allows the benchmarking of water use and production across fields, farms and catchments when combined with yield data at the end of season. This benchmarking information has been seen as a valuable tool for improving water use efficiency and resource use efficiency. This project has provided benchmarking data available across three catchments and over approximately 80 000 ha of cotton during the 2011/2012 irrigation season. This information has been provided to irrigators to allow them to directly compare their performance against others in the industry and also look at options for improving their own water use productivity. Continued use and expansion of the approach has the potential to lead to wide scale change in water use management across a range of scales from individual fields to regions.

Part 3 – Final Report Guide (due 31 October)

Background

Irrisat is a weather based irrigation scheduling and benchmarking service. While the main scheduling tool used in the cotton industry is soil moisture monitoring, they are single point measurements. It is recommended that a variety of tools be used including visual, soil moisture monitoring and weather based scheduling methods. Weather based methods have previously not been adopted due to the lack of reliable evapo-transpiration (ET_o) data and site specific crop coefficients.

Irrisat uses satellite imagery to determine site specific crop coefficients that are needed to calculate crop water use. The system uses local weather stations to measure sunlight hours and intensity, cloud cover, rainfall and wind which are all used to calculate a reference crop water use in the past 24 hours. This information when combined with the satellite-determined crop coefficient for a particular crop allows a site specific crop water use figure to be calculated. The approach can be used over large areas at a low cost.

The Irrisat system was applied in an initial trial within the cotton industry in the Gwydir catchment during the 2010/2011 irrigation season. Ten consultants took part in the trial with 304 individual paddocks or blocks being monitored through the irrigation season. Total area monitored was approximately 20 000 ha.

Based on the results of the trials and feedback received from the trial participants three applications were identified where the Irrisat technology could benefit the cotton industry:

- Irrisat for Irrigation Scheduling and Management
- Irrisat for regional WUE benchmarking
- Irrisat as an in season yield prediction tool

It was indicated by the trial participants that there were areas which need further development with Irrisat to refine the approach and link with existing technologies such as soil moisture probes and other 3rd party industry water management tools. This Phase II project was undertaken further investigate the above applications and extend and expand the Irrisat trial into other cotton growing regions.

Objectives

Feedback received at field days and conferences attended during the initial project found a number of consultants and irrigators wish to continue to use the Irrisat product across the cotton growing valleys to improve water use efficiency in cotton crops. Based on the feedback received, the following objectives were proposed for this Phase II project for the 2011-2012 season:

Irrisat for Irrigation Scheduling and Management

Improvements will be made on the interface for growers and consultants with multiple blocks to reduce the time needed to update the field based information. Additionally spatial field

based data will be included in the web interface for individual growers along with the provision of a 7 day ETo forecast. Integration with other inputs, like soil moisture data, will be initiated during the 2011-2012 season. It is proposed that discussions begin with soil moisture monitoring providers (eg Sentek, Research Services New England) to see how crop water use data could be integrated with soil monitoring information.

- IrriSat for regional WUE benchmarking

Data analysis processes will be automated to enable WUE benchmarking. Data availability through the web-portal to enable and visualize benchmarking will be improved, based on feedback and requests obtained from the 2010-2011 season. Additionally, the development of individual benchmarking reports for growers will be investigated.

- IrriSat as an in season yield prediction tool

Based on experiences during and after the 2010-2011 growing season, it appears that yield forecasting can be applied starting in January. Further development of this approach, as well as predictions on field based yield, applied to a basin/valley level will be included in the 2011-2012 activities. The data from additional irrigated regions in the trial will be used to refine relationships for potential yield forecasting from cumulative measured crop evapotranspiration.

Methods

The IrriSAT trial was continued and expanded during the 2011/2012 irrigation season. Approximately 50 growers and consultants were engaged in the trial across three catchments with the total cotton area monitored approximately 80 000 ha. An additional weather station was also added to the IrriSAT network at Walgett in late 2011 to accommodate the Walgett growers. A brief description of the IrriSat approach is described below.

How IrriSAT Calculates Crop Evapotranspiration (ETc)

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. Satellite derived vegetation images are used to derive the crop coefficient values. On-ground weather station networks are used to calculate reference evapotranspiration (ETo). This reference evapotranspiration is used to represent the climatic conditions under which evapotranspiration takes place, which is then used to calculate actual evapotranspiration (ETc) for specific crops by multiplying the ETo by a specific crop coefficient (Kc). 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. Therefore ETc for a specific crop is given by: $ETc = ETo \times Kc$.

Figure 1 shows an overall flow diagram of the IrriSAT system. Two information feeds (ETo from on-ground weather stations and forecast ETo) are combined with satellite derived crop coefficients to determine individual paddock water use on a daily basis. This information is then processed and delivered through a web based interface to irrigation managers. This

information on crop water use can also be used for benchmarking and water use productivity investigations when combined with yield data from the monitored fields.

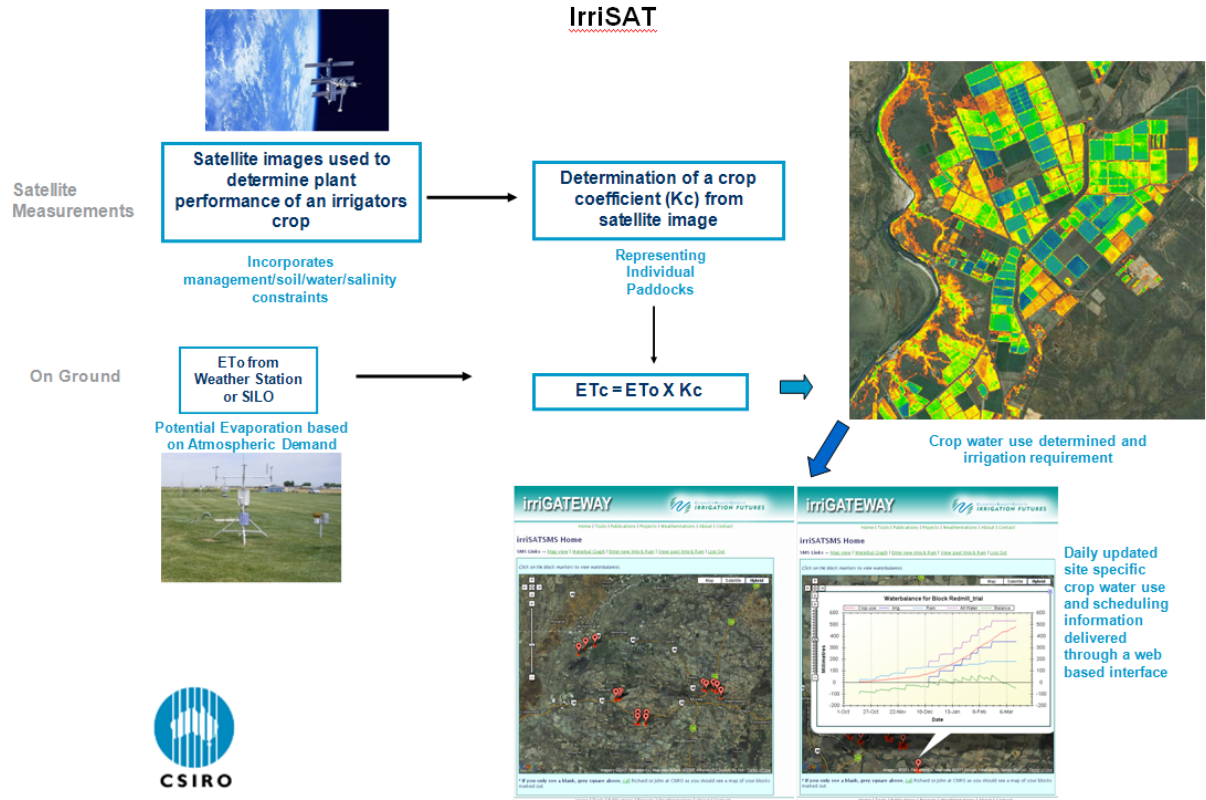


Figure 1: IrriSAT system showing information flows and linkages between sensing and information delivery platforms

Reference Evapotranspiration and Rainfall:

As with last year, the cotton regions experienced high rainfall leading to major flooding in some areas, along with lower evapotranspiration (ETo) rates for the regions when compared to the historical average. Table 1 below summaries the weather conditions experienced across the regions for 2011-12, whilst Figure 2 depicts the cumulative seasonal ETo values at each location for the 2011-12 irrigation season. Mean temperature, mean relative humidity and radiation were similar across the weather station network. The higher ETo rates observed at Keytah are explained by higher wind values along with slightly more radiation observed. The lower rates of ETo observed at Narrabri is due to significantly less wind run measured at this location when compared to the three other weather stations. The Narrabri station is run by CSIRO Plant Industry at Myall Vale, whereas the other three stations are operated by CSIRO Land and Water. Trial participants had individual fields associated with the closest ETo weather station.

Table 1: 2011-2012 Seasonal Weather Summary (15/10/2011-30/04/2012)

Station	Temp deg C	Rel. Hum. %	Radiation MJ/m ²	Wind km/hr	Rain mm	ETo mm
Keytah	23.0	60	23.7	10.7	674	1066
Weemelah	23.4	60	22.2	9.3	597	1015
Walgett	23.2	60	22.6	9.7	656	1019
Narrabri	22.7	63	22.4	6.2	770	912

Note: Walgett weather data has been used from the Weemelah site until Walgett started recording on 1-Jan-2012.

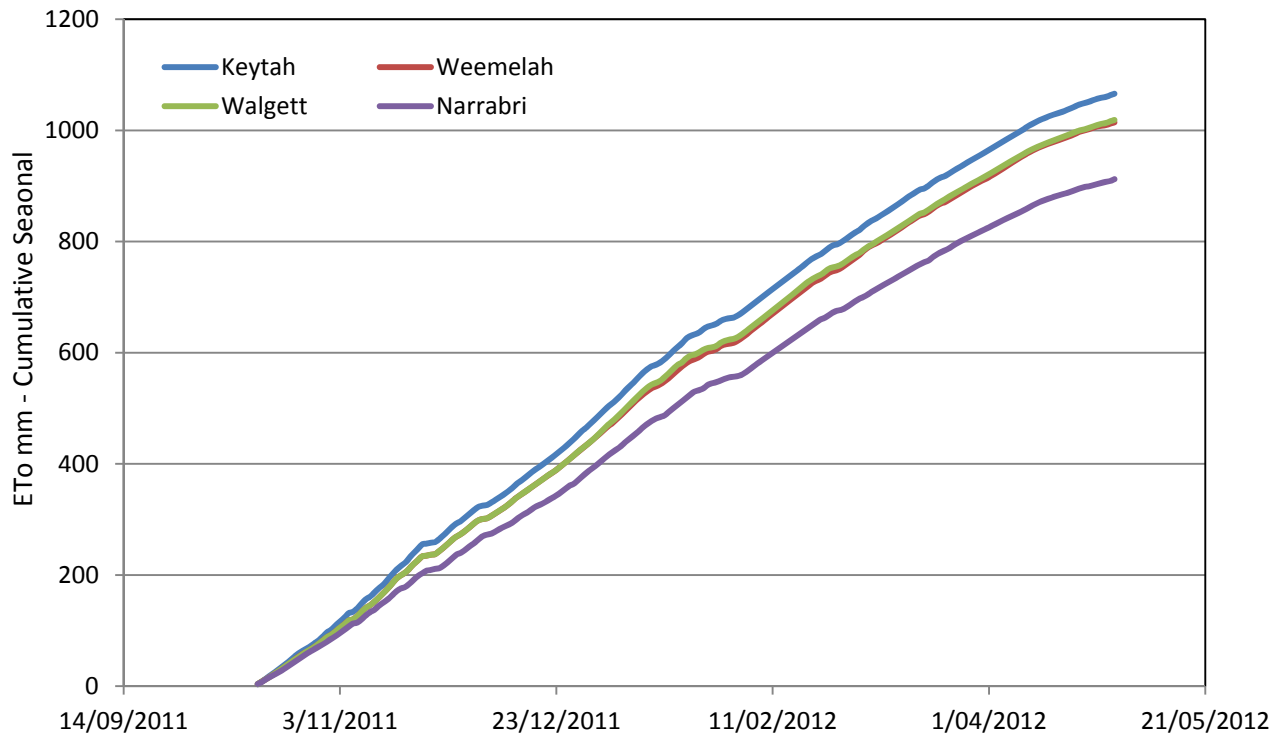
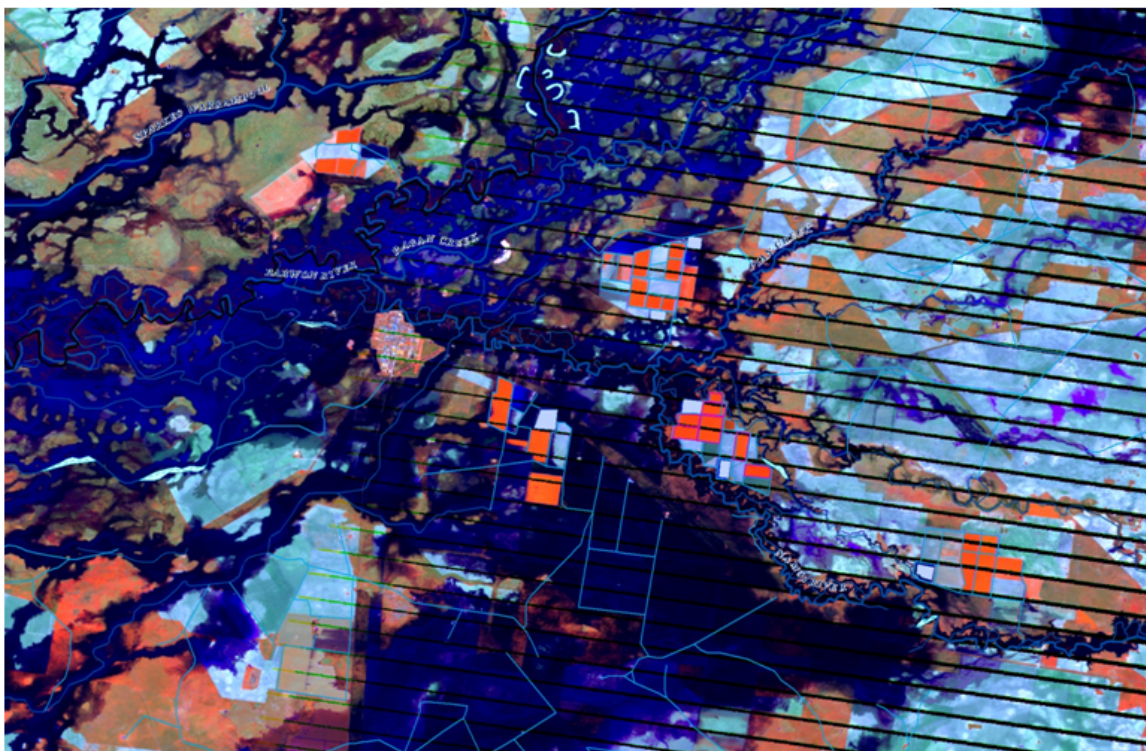


Figure 2: Cumulative seasonal ETo across 4 weather stations for 2011-12

Landsat 5 Satellite Issues:

During the 2011/2012 irrigation season we had issues with the Landsat 5 satellite maintained by NASA and the USGS. Landsat 5 was launched in 1984 and was designed to last 3 years. In November 2011, the U.S. Geological Survey (USGS) stopped acquiring images from the 27-year-old Landsat 5 Earth observation satellite due to a rapidly degrading electronic component. Instead of continuing to operate until the amplifier failed completely, USGS engineers suspended imaging activities for an initial period of 90 days in order to explore every possible option for restoring satellite-to-ground image transmissions, this occurred in Nov 2011.

Landsat 5 was providing better data than the younger Landsat 7 satellite. The USGS operated Landsat 7 remains in orbit collecting global imagery. Since its launch in 1999 with a 5-year design life, Landsat 7 has experienced an instrument anomaly in 2003 which reduces the amount of data collected per image. The faulty part is called the scan line corrector, a mirror-like assembly that compensates for the "zigzag" motion of the image scans by the Enhanced Thermal Mapper Plus instrument. Due to the glitch, each scene is missing about 22 percent of data, leaving gaps in image acquisitions (Figure 3). We have had to use solely Landsat 7 to complete the 2011/2012 season trials which has limited our data somewhat for this season and our ability to provide real-time scheduling information. The launch of the Landsat Data Continuity Mission, which will become Landsat 8, is scheduled for March, 2013. This will ensure future remote sensing data availability for the IrriSAT system from March 2013 onwards.



17-Feb-2012

20 km

Figure 3: Landsat 7 image showing data gaps present from the failed line scanner

Results

IrriSat for Irrigation Scheduling and Management

The IrriSAT system is able to provide a low cost, site specific irrigation water management tool that can be applied over large areas. The IrriSAT web portal is available in a Google maps interface which allowed consultants to monitor between 10-50 individual irrigation management units or fields. For each management unit, waterbalance information was calculated from the IrriSAT system and displayed in a cumulative graph over the irrigation season. Data is updated daily using weather station data and forecast ETo combined with satellite derived kc data which is updated on a 7-14 day interval. During this seasons trials we

had issues with the Landsat 5 satellite, as discussed above, which provides a large proportion of the real-time crop remote sensing data. While the Landsat 7 satellite was still available, data coverage issues (mentioned above) and loss of the dual satellite repeat cycle meant it was difficult to adequately assess the success of this objective of the trial. Comparisons at the end of the season showed good relationships, as in previous seasons with cumulative water use estimates measured on ground. Improvements were made to the IrriSAT web interface to allow growers to see spatial data across their fields (Figure 4), however this functionality was lost once Landsat 5 stopped transmitting images so the project had a limited time to collect feedback from participants on these improvements during the 2011/2012 irrigation season. The interface was also improved to allow easy entry of data for users with multiple fields based on feedback from the initial group of trial participants.

Gwydir (prototype)

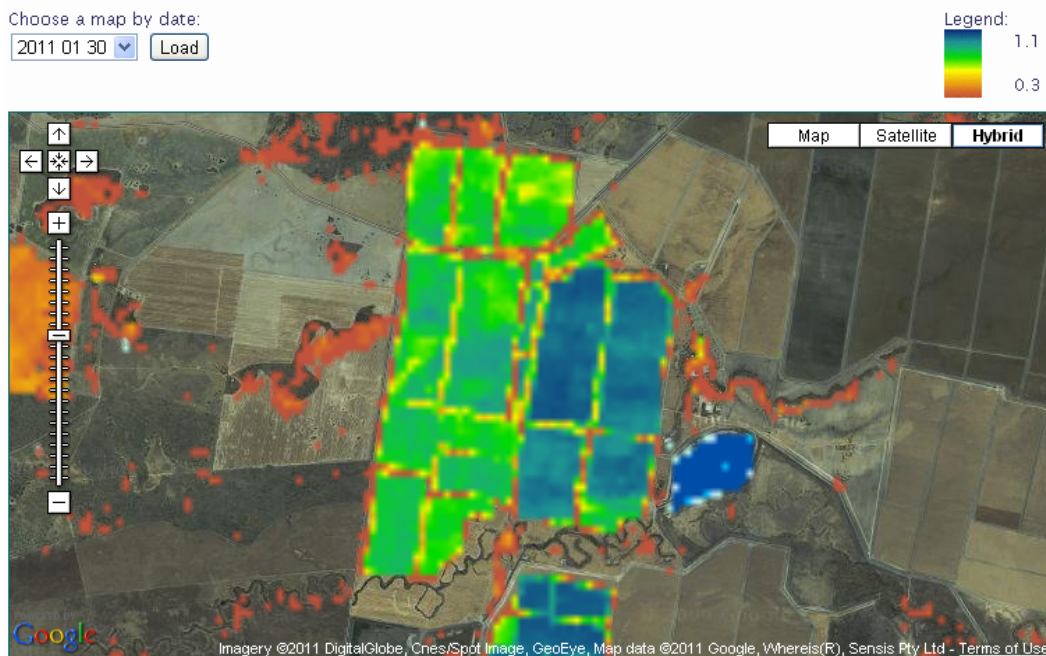


Figure 4 Spatial variation in crop coefficients across irrigated fields as shown in the IrriSAT web portal.

Efforts to integrate IrriSAT crop water use data with soil monitoring information has been undertaken with initial discussions being undertaken with a number of soil moisture monitoring providers (eg Sentek, Research Services New England). This has been beneficial in developing a path forward for integrating data feeds of real-time crop water use information derived from IrriSAT into additional information packages. The project team has developed an ftp feed of IrriSAT derived water information which can be provided to easily integrate this information into additional third party products. We also hope to offer this information to improve other industry packages in future such as WaterSched2, CropWaterUse, Watertrack which rely on accurate measurements of crop water use and currently use default values from FAO 56.

IrriSat for regional WUE benchmarking

One of the benefits of the IrriSAT approach is that it covers large areas at low cost and provides estimates of actual crop evapotranspiration data that can be used for benchmarking the

performance of cotton crops. The approach is universal across regions so allows direct comparisons to be made and the development of robust benchmarking data. This feature was seen by the trial participants as extremely useful in being able to benchmark water use efficiency across a region combined with yield and/or financial data for benchmarking and decision making purposes. Additionally this season the trial expanded to cover three cotton producing regions – Gwydir, Namoi and Walgett. Figure 5 shows total seasonal crop water consumption and yield across the Gwydir, Namoi and Walgett cotton regions for the 2011/2012 irrigation season. It can be seen that there was a clear relationship between IrriSAT measured crop evapotranspiration and measured yield. The relationship was particularly strong on the irrigated crops which were monitored with the system (i.e. IrriSAT Crop Evapotranspiration figures above 4 ML/ha). The relationship between yields and measured ETc from IrriSAT where not as strong as in non-irrigated crops and this is most likely due to stress factors not providing sufficient feedback from the NDVI measurements used in IrriSAT. However, overall relationships where still very strongly correlated ($R^2 = 0.74$ when analysed for all regions). Feedback from the trial participants indicated that this water use productivity benchmarking using the IrriSAT approach was a valuable tool to track performance of individual fields and also to show how it compares to other water users and regions.

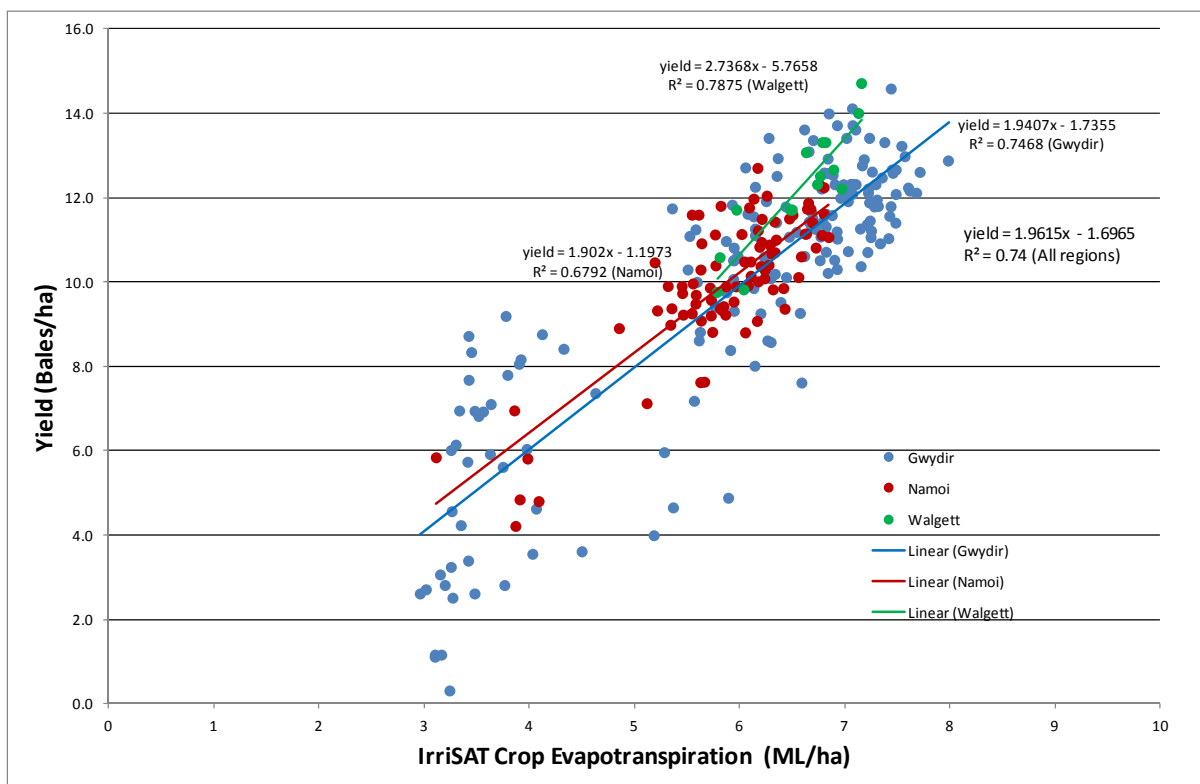


Figure 5 IrriSat ETc and yield relationship for 2011/2012

Each trial participant was provided with a summary report at the end of the season showing this benchmarking data and also identifying their individual fields within the data.

IrriSat as an in season yield prediction tool

The strong relationship between IrriSAT derived crop evapotranspiration and yield potentially allows for approximate yield forecasting to be undertaken before harvest in future seasons using the relationships developed in this project across the three regions, Figure 5. Realistically, on a practical leave, an estimate would likely be within 2 bales/ha based on the results and relationships determined during monitoring in this project. Results from the previous seasons trials and this seasons trials indicate that the relationships will be useful inter-seasonal and well as inter-regional for predicting/forecasting potential yields. There was not a large difference between relationships of cumulative crop evapotranspiration and yield over the three regions, which gives confidence in using the approach in a predictive fashion across the industry. Cumulative crop evapotranspiration as calculated by IrriSAT would be able to provide an approximate estimate of yield using solely remote sensed data. Additional data such as fruit/boll counts measured on-ground could potentially further improve this yield forecasting ability. The results from the IrriSAT derived crop evapotranspiration tend to indicate that there are differences between the ability of different fields to convert crop evapotranspiration into yield potential and based on similar experiences with grapevines this is likely due to the fruit load/canopy cover ratio's, hence additional on-ground measurements may overcome this issue.

Outcomes

The project has placed the cotton industry at the forefront of water management technologies. The IrriSAT system provides water management information over large areas at low cost to improve water use efficiency. The IrriSAT system also allows the benchmarking of water use and production across fields, farms and catchments when combined with yield data at the end of season. This benchmarking information has been seen as a valuable tool for improving water use efficiency and resource use efficiency. This project has provided benchmarking data across three catchments and over approximately 80 000 ha of cotton during the 2011/2012 irrigation season. This information has been provided to irrigators to allow them to directly compare their performance against others in the industry and also look at options for improving their own water use productivity. The technology developed in the project and applied to measuring cotton evapotranspiration can also potentially be incorporated into a number of third party products which are used within the industry that require more accurate measurements of crop water use.

1. Please describe any:-

- a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
No additional patents or licences were developed during this phase of the project
- b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
No additional discoveries were developed during this phase of the project
- c) required changes to the Intellectual Property register.
No changes are required

Conclusion

The IrriSAT approach has the potential to provide a significant benefit for the Australian cotton industry. This extension of the trial has shown the potential of the IrriSAT system for providing site specific irrigation scheduling information, regional water use benchmarking and potentially in season yield forecasting. Each one of these components has clear benefits for the cotton industry which were identified by the trial participants. From this extension trial it was clear that there is significant interest in the approach by water managers in the cotton industry and benefits for water management. Continued use and expansion of the IrriSAT approach has the potential to led to wide scale change in water use management across a range of scales from individual fields to regions.

Extension Opportunities

2. Detail a plan for the activities or other steps that may be taken:
 - (a) to further develop or to exploit the project technology.

There is a large opportunity to further extend this research and application within the cotton industry. Project participants have provided feedback that they see value in the information provided with the technology and also value in the ability of the system to provide industry wide and inter region water use productivity information which can be used in water management. We are currently investigating further opportunities to continue to provide this information. During March 2013 we will also hold a training workshop for consultants and industry people who wish to use the IrriSAT approach in their own applications. We have been working with a partner in the EU Space Agency Extension Programme and now have access to free remote sensing analysis software which can be used for undertaking the IrriSAT analysis. Workshop participants will be given the software, shown how to access the free USGS Landsat images and shown how to implement the IrriSAT approach for determining crop water use.

- (b) for the future presentation and dissemination of the project outcomes.

Results from these seasons' trials have already been presented at a number of industry events and are shown in the preceding section. As opportunities arise we will endeavour to further communicate the results from the project across the cotton industry. A journal article from the inter region benchmarking assessment of water use and yields is currently being developed for publication. This material will also be presented at the 2013 Irrigation Association of Australia conference.

- (c) for future research.

With increasing pressure being placed on water resources within the irrigation sector in the Murray Darling Basin, having an industry standard water use productivity benchmarking and water management tool is particularly important, that is accurately directly measuring crop water use. Applications such as IrriSAT provide actual site specific water use management information across large area's at low cost at various time and spatial scales which have been shown to be potentially very useful in cotton production systems. Future research within this area should focus on providing a consistent and sustainable approach for providing this

information across the industry. Potential also exists to further refine the technology and its accuracy and also to improve the yield forecasting ability using additional simple on-ground measurements of fruit/boll counts at specific periods in the season to combine with the remote sensed evapotranspiration data.

9. A. List the publications arising from the research project and/or a publication plan.

Industry Journal & Conference

Hornbuckle, J. & Soppe, R. (2012) *Space-age technology used industry-wide*, Australian Cotton Water Story – A decade of Research & Development, Cotton Catchment Communities CRC, pp. 22 <http://www.cottoncrc.org.au/industry/Publications/Water>

Montgomery, J., Soppe, R. Hornbuckle, J. (2012) *Piloting IrriSAT Technology in Irrigated Cotton*, 16th Australian Cotton Conference – Growing Better all the Time, Broadbeach, Gold Coast, Australia, 2012 *Poster presentation*

Montgomery, J., Soppe, R. Hornbuckle, J. (2012) *Piloting IrriSAT Technology in Irrigated Cotton*, 16th Australian Cotton Conference – Growing Better all the Time, Broadbeach, Gold Coast, Australia, 2012 *Paper presentation*

Soppe, R., Hornbuckle, J.W. & Montgomery, J. (2012) *Cotton water productivity in the Gwydir, NSW*, Irrigation Association of Australia Conference, Adelaide, June 2012, <http://www.irrigation.org.au/index.cfm?publications/2012-ial-conference-papers>

Emma Leonard (2012) *Spatial prediction of soil water*, SPAA Precision Ag News, Volume 8, Issue 2 Autumn 2012 www.spaa.com.au pp.22-23

Montgomery, J., Hornbuckle, J. & Soppe, R. (2012) *Determining crop water use with IrriSAT*, The Australian Cottongrower, December 2011- January 2012, pp. 18-20 <http://www.greenmountpress.com.au/cottongrower/Back%20issues/327djcot11/327djcot11.pdf>

Newspaper

Agriculture Today, Crops and Grains, *Walgett improves water*, p.12 Thursday, March 1, 2012

CHAPTER 1: The Farm

Space-age technology used industry-wide

■ John Hornbuckle and Richard Soppe, CSIRO

IN BRIEF...

- IrriSAT is an industry wide, high resolution, low cost crop water use and benchmarking service.
- Provides daily crop water use information and also predicts crop water use for the coming seven days.
- Uses a web interface which was developed using Google Maps and allows consultants to easily monitor multiple farms and fields.
- System has its greatest strengths in benchmarking crop water use productivity across farms and regions.

AN industry wide, high resolution, low cost crop water use and benchmarking service – that's been the goal of the IrriSAT system being developed and trialed over the 2010–11 and 2011–12 irrigation seasons on more than 80 000 ha of cotton fields. The technology makes use of satellite imaging for monitoring crop growth and a series of weather stations spread throughout the cotton growing areas to produce high resolution site specific crop water use information on a daily basis which can be used for water management and also benchmarking. The technology also includes a seven-day weather forecast for short-term irrigation water management decisions.

IrriSAT uses a web interface developed using Google Maps and allows users to easily monitor multiple farms and fields. Users upload three pieces of irrigation information: irrigation date; amount of irrigation water applied and daily rainfall. IrriSAT regularly obtains satellite imagery to determine current crop growth through a measure of the Normalised Difference Vegetation Index (NDVI). These NDVI values are then correlated to an individual crop coefficient. The satellite derived data is then combined with local weather station data to provide an accurate measure of daily crop water use and a prediction of crop water use for the coming seven days.

This is useful information to help with water management decisions. Spatial crop water use information determined by IrriSAT is also available through the interface and allows users to investigate water use differences within and between fields using the system (Figure 1). This information can be used to change management decisions or to gain a better understanding of how or why fields might be affected by different management options.

One of the great strengths of IrriSAT is it is able to cover entire irrigation regions using remote sensed satellite imaging which allows benchmarking of crop water use index (CWUI) across a farm or across an entire irrigated region or catchment. It provides a regional snapshot of the performance of row configurations, irrigation systems and irrigation deficit management strategies which can be seen to affect yield and water use efficiency performance.

At this early stage the IrriSAT system has been trialed with both consultants and directly with irrigators across the Gwydir region for the 2010–11 and 2011–12 seasons and the Namoi and Border Rivers for the last irrigation season. This adaptive research

FIGURE 1: Spatial crop water use differences across irrigated cotton fields determined by IrriSAT.



and extension has allowed the system to be improved each year to focus on the key questions and delivery of information which really assists in developing this tool for universal use.

So far the feedback we have received has been very positive and most see the IrriSAT system as a tool which has its greatest strengths in benchmarking crop water use productivity across farms and regions to see where improvements can potentially be made.

Rob Holmes, HMAg, Moree says the greatest use he has for using IrriSAT crop water use information was for benchmarking his clients' cotton crops.

"When I'm calculating the crop water use index I need a reliable estimate of ETC. The IrriSAT technology has provided me with this," Rob said.

"It's quick and easily obtained for my end-of-season benchmarks. It reflects the whole paddock, rather than just a single square metre of the paddock.

"Benchmarking crop water use allows me to look back over the season with my clients and compare crop productivity in terms of water use between fields and farms. We can discuss what might be occurring in field and try to improve over time."

As we move forward with water management, we believe tools such as IrriSAT will be able to play a key part in understanding how to best make use of water across not just a paddock but also a farm or catchment.

Funding: Cotton Research and Development Corporation

Further reading at www.crdc.com.au

Piloting IriSat Technology in Irrigated Cotton

Janelle Montgomery¹, Richard Soppe & John Hornbuckle²

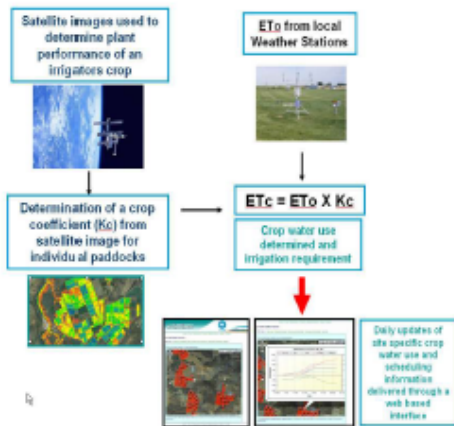
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 2. CSIRO Land and Water, Griffith, NSW, 2680, Australia, richard.soppe@csiro.au

Developed by CSIRO, IriSat is a weather based irrigation scheduling service. It uses satellite imagery to better determine site specific crop coefficients (Kc) that are needed to calculate crop water use.

It involves the installation of two weather stations across a region so local estimates of reference crop evapotranspiration (ET₀) can be obtained. Kc is combined with ET₀ to calculate crop water use (ET_c).

It has been trialled in irrigated cotton over three seasons and although developed primarily as an irrigation scheduling tool, an unexpected outcome has been the interest in using the technology for irrigation benchmarking.

How does IriSat Work?



Uses of IriSat:

1) Determine seasonal and daily crop water use. The red line in figure 1 shows the cumulative crop water use over the season. Daily crop water use information can also be downloaded from the website.

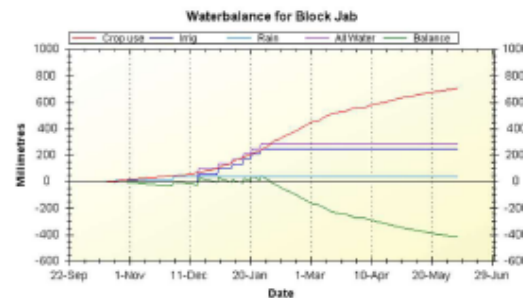


Figure 1: Water balance graph for an individual irrigation field

2) Forecast daily crop water use. IriSat predicts crop water use for the coming 7 days. This is very useful information to help with scheduling decisions.

3) Examine spatial variability across a field or multiple fields over a region. The crop coefficient (Kc) map (figure 2) shows the variability in the field, different stages of crop growth, impacts of waterlogging, insect pressures, nutrition etc.



Figure 2: Variation in crop coefficient across fields and farm

4) Benchmark Crop Water Use across a farm and region.

IriSat can be used to determine Crop Water Index, which relates yield to actual crop water use. Figure 3 illustrates the difference in crop productivity between fields monitored during 2010-11 season. It includes a variety of irrigation systems and row configurations

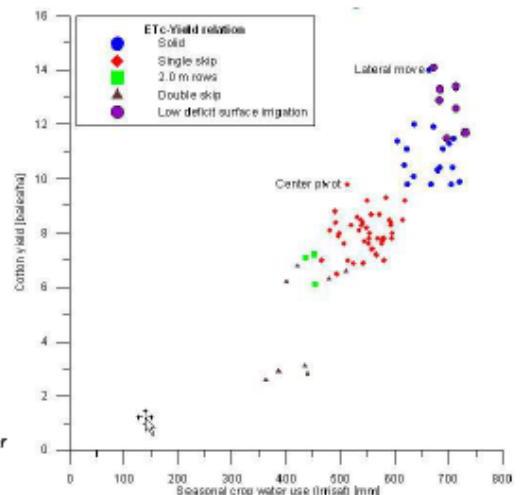


Figure 3: Cotton yield and seasonal crop water use for different row configurations and irrigation methods in the Gwydir catchment, NSW for the 2010-2011 season



PILOTING IRRISAT TECHNOLOGY IN IRRIGATED COTTON

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SUMMARY

Developed by CSIRO, IriSat is a weather based irrigation scheduling service. It uses satellite imagery to better determine site specific crop coefficients that are needed to calculate crop water use. It has been trialled in irrigated cotton over three seasons and although developed primarily as an irrigation tool, an unexpected outcome has been the interest in using the technology for irrigation benchmarking.

BACKGROUND

Developed by CSIRO, IriSat SMS is a weather based irrigation scheduling service. It uses satellite imagery to better determine crop coefficients that are site specific for individual irrigators which are then combined with reference evapotranspiration to calculate crop water use (Hombuckle et al. 2009). It also provides customised irrigation scheduling information which is sent to irrigators by SMS messaging or via an internet website.

Following the successful use of the IriSat SMS service in the Murrumbidgee Irrigation Area with grape and citrus irrigators, it was trialled for the first time in irrigated cotton in the Gwydir valley in northern NSW during the 2009/10 cotton season by two cotton consultants. This trial was extended to include 10 cotton consultants located in the Gwydir and Border Rivers region during the 2010/11 season and further extended to include the Lower Namoi valley in 2011/12.

METHODS

The IriSat service involves the installation of a network of 2 to 4 weather stations across the area so reliable estimates of ETo can be obtained. Satellite images are used to frequently determine crop coefficients for individual fields over the entire growing season. These satellite images show different vegetative growth stages of the crops growing in the region which can be directly related to a site specific crop coefficient.

Researchers have found a strong relationship between Normalized Difference Vegetation Index (NDVI) and crop canopy cover (Hombuckle et al. 2010). Canopy cover is a direct driver of crop water, allowing a clear relationship to be developed between NDVI values and crop coefficients. This relationship has been found in a large range of crops, however this is the first time the relationship has been established for broadacre irrigated cotton in Australia.

Thenceforth, once the NDVI data has been derived for a particular crop and field, it is converted to a Kc value and crop water use is determined by combining Kc with the ETo data collected from a nearby weather station.

IriSat uses a web interface which was developed using Google maps, and allows consultants to easily monitor multiple farms and fields. Irrigators need to upload three pieces of irrigation information; 1) irrigation date, 2) amount of irrigation water applied and 3) daily rainfall.

IriSat provides daily crop water use information and also predicts crop water use for the coming 7 days. This is useful information to help with water management decisions.

Spatial crop water use information determined by IriSat is also available through the interface and allows users to investigate water use differences within and between fields using the system. This information can be used for changing management decisions or gaining a better understanding of how or why fields might be affected by management decisions.

DISCUSSION AND RESULTS

The consultants involved in the trial have provided valuable feedback to CSIRO researchers on how the technology could be best utilised in the cotton industry.

The trial has found a variety of uses for the IriSat technology. As an irrigation scheduling tool, it can be used to determine seasonal and daily crop water use. The red line in Figure 1 shows the cumulative crop water use over the season. Daily crop water use information can be downloaded from the website.

The data is also useful for looking retrospectively at irrigation management

Consultant comment: "It was pretty handy looking back at the data at the end of the season. There was a good correlation between field yields and water use. We could look at the data and discuss why this correlation was occurring eg did the paddock require laser levelling, was it the last block to be irrigated, compaction issues?? It is a good check of what we had hypothesised."

IriSAT can also be used to examine spatial variability across a field or multiple paddocks over a region. Figure 2 shows the variability in the paddock, different stages of crop growth, impacts of waterlogging, insect pressures, nutrition etc.

An unexpected outcome has been the interest in using the technology for irrigation benchmarking. In fact most of the consultants see the IriSat system as a tool which has its greatest strengths in benchmarking crop water use productivity across farms and regions, to see where improvements can potentially be made. IriSat can be used to determine the Crop Water Use Index, which relates yield to actual crop water use.

Consultant Comment

"The greatest use I have for using IriSAT Etc information is for benchmarking my clients cotton crops. When I'm calculating the crop water use index I need a reliable estimate of ETC. The IriSAT technology has provided me with this. It's quick and easily obtained for my end-of-season benchmarks. It reflects the whole paddock, rather than just a single square metre of the paddock. Benchmarking crop water use allows me to look back over the season with my clients and compare crop productivity in terms of water use between fields and farms. We can discuss what might be occurring in field such as compaction, what areas are performing well etc and try to improve over time."

Figure 3 illustrates differences in crop productivity between the fields monitored during the 2009/10 & 2010/11 seasons. It includes a variety of irrigation systems and row configurations.

The solid and single skip planting configurations from the different farms cluster well together, showing clear thresholds in yield and seasonal crop water use for the different planting configurations.

An outlier in the solid planting configuration was irrigated with a lateral move, while the other irrigation systems in the cluster were watered with furrow irrigation. Whilst the lateral move irrigated cotton used a similar amount of water to other solid planted crops, it produced higher yields than the furrow irrigated fields (thus, a higher crop water productivity). A smaller group of data in the solid planting configuration is shown as a low deficit system. These fields were managed by a consultant emulating an irrigation frequency and application similar to the lateral move operation, using a lower deficit and more frequent applications of irrigation water. It can be seen that the low deficit fields consumed more water, but resulted in higher yields, and in general had a higher crop water productivity than the other solid furrow irrigated fields.

The consultants agree that the tool has enormous potential. Although it would not replace soil probes, they thought the technology has the potential to add value to irrigation scheduling decision making.

CONCLUSIONS

IriSat is seen as another option within the 'Scheduling Tool Box' but with the advantage of low cost and wide coverage as the satellite images are available right across Australia. There is also strong interest in using IriSat as an benchmarking tool to assess crop productivity over a large spatial scale.

The technology has been proven to provide useful irrigation water management information in a number of irrigated cropping commodities across Australia. This recent research has shown the IriSat approach provides useful information at a range of time and spatial scales across irrigated cotton enterprises. Further work now needs to be undertaken to integrate and automate the approach for the cotton industry.

ACKNOWLEDGMENT

The authors would like to gratefully acknowledge the assistance provided by CRDC in funding this research and the consultants who took part in the trial.

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- Hornbuckle, J., Christen, E., Car, N. & Smith, D. (2010) Convenient and low cost irrigation scheduling – an opportunity for irrigators, Australian irrigation Conference 2010, Darling Harbour Sydney, 8-11th June 2010

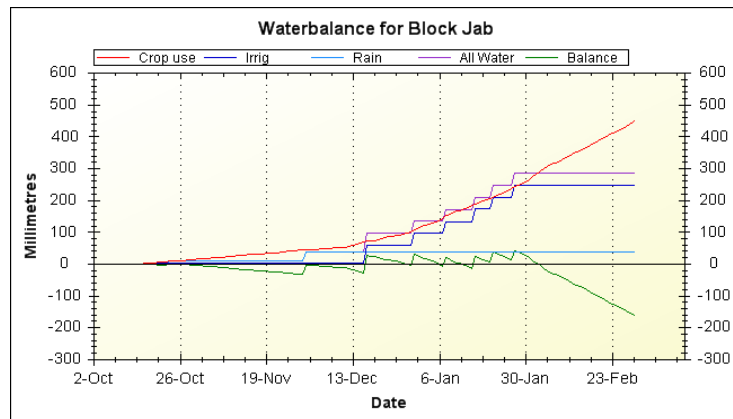


Figure 1: Waterbalance graph for an individual irrigation field



Figure 2: Variation in crop coefficient across fields and farm.

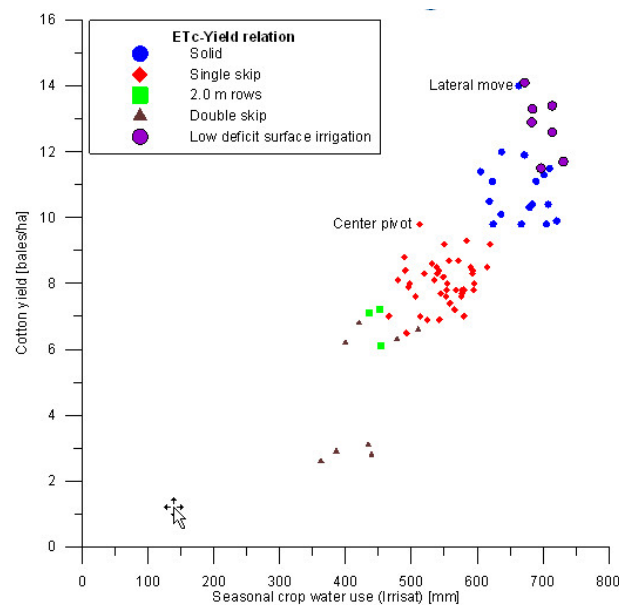


Figure 3: Cotton yield and seasonal crop water use for different row configurations and irrigation methods in the Gwydir catchment, NSW for season 2010-2011

Cotton water productivity in the Gwydir, NSW

Richard Soppe^{1*}, John Hornbuckle¹ and Janelle Montgomery^{2*}

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IAL 2012 National Conference

Summary

Crop water consumption and yield data were collected for cotton, grown under different row configurations and irrigation regimes in the Gwydir in 2010-2011. Crop water productivity was calculated and indicated that under the climatic conditions of the 2010-2011 season a high frequency, low volume irrigation regime resulted in better crop water productivity. Skip-row and double-skip row configurations had reduced yield, comparable with the reduced number of plants in a field.

Introduction

Increasing crop water productivity, a higher crop yield per unit applied water (more crop per drop), is one of the objectives in areas where water is a scarce good. Water availability in The Murray Darling basin is limited, and the basin is going through a period of serious discussions on redistributing water to different water use sectors. Cotton is one of the crops cultivated in the Gwydir catchment in the north of NSW. This study evaluates cotton water productivity under a range of conditions using remote sensing observations combined with actual crop yield values.

Methods and Materials

Two representative agro-meteorological stations were installed in the Gwydir catchment measuring the elements needed to calculate reference evapotranspiration (radiation, temperature, humidity and wind speed). Landsat 5 remote sensing images were downloaded regularly. Digital numbers were converted to radiance and reflectance (Landsat handbook), and the normalized difference vegetation index (NDVI) was then calculated. Based on the NDVI, a crop cover percentage was obtained, and the crop cover was related to a field specific crop coefficient using the method of Trout et al (2007). Crop coefficients and reference evapotranspiration were combined for each field to calculate actual crop water use through the IrriSat system. In IrriSat, growers receive the information on crop water use, and enter data on rainfall and irrigation timing to allow a water balance tracker throughout the growing season. Cotton yield data were collected at the end of the season from

growers participating in the IrriSat system and were based on field averaged yields based on cotton-gin measurements. Data were collected in the 2010-2011 growing season. Crop water productivity was calculated as the yield divided by the consumed crop water over the season.

A research trial was conducted in the Gwydir catchment in the same year, including different types of row configurations and irrigation scheduling. Typical row configurations in cotton are the solid planting, skip-row planting, leaving every other row empty and double skip-row, leaving two rows empty and planting the third row. Although most productive cotton fields are irrigated, some areas are planted as rain-fed cotton. Techniques like skip-row, double-skip and rainfed are used to reduce risk of uncertain irrigation supply and rainfall. Skip and double skip row configuration expand the area of effective rainfall per row of planted cotton. Effectiveness of these configurations is largely season dependent.

Results and Discussion

The calculated crop water productivity for a variety of systems is shown in figure 1. The solid and single skip planting configurations from the different farms appear to cluster well together. An outlier in the solid planting configuration was irrigated with a lateral move, while the other irrigation systems in the cluster were irrigated with surface irrigation (mainly applications through siphons). The lateral move irrigated cotton used an average volume of water throughout the season, but produced higher yields than the surface irrigated fields (thus, a higher crop water productivity). A smaller group of data in the solid planting configuration is shown as a low deficit system. These fields were managed by a consultant who used rapid advance surface water applications, thus reducing the volume of application, and increasing the frequency of irrigations. This emulated an irrigation frequency and application similar to the lateral move operation. From the dataset, it can be seen that the low deficit fields consumed more water, but resulted in higher yields, and in general had a higher crop water productivity than the standard irrigated fields.

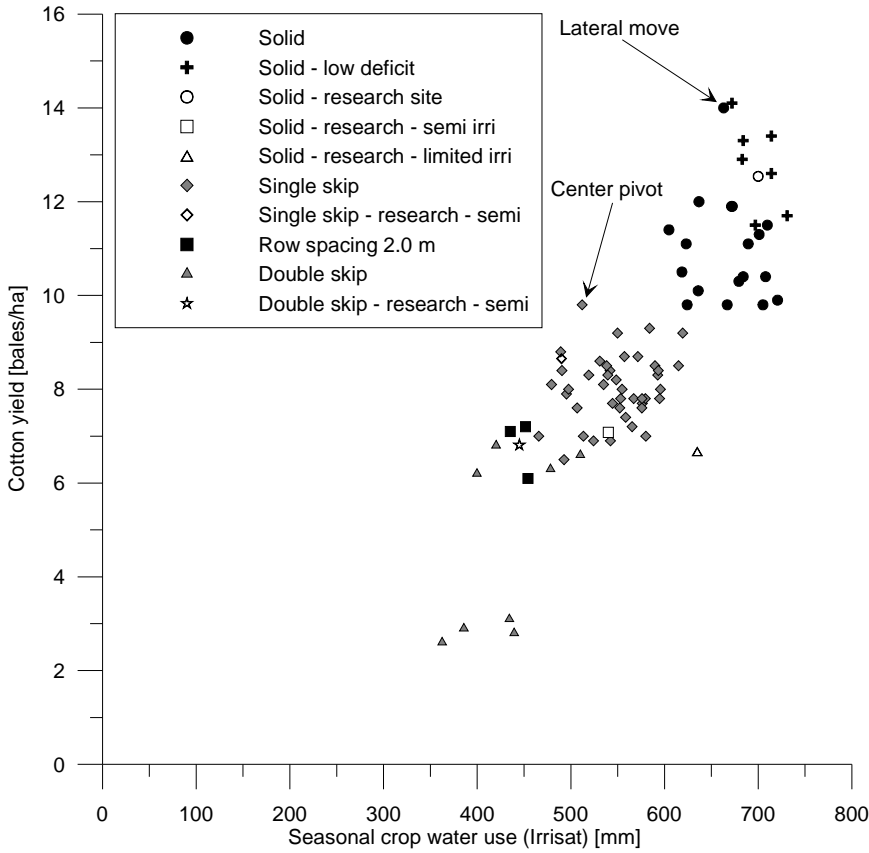


Figure 1: Cotton yield and seasonal crop water use for different row configurations and irrigation methods in the Gwydir catchment, NSW for season 2010-2011

The solid planting configuration in the research plot fell within the standard and low deficit group of data points. In the single skip data set, one data point resulted in a relatively high crop water productivity. This point is indicated in the graph as a center pivot irrigated field. The center pivot, similar to the lateral move, applied high frequency irrigation with low volumes. The double skip group of data was divided into two groups, one with additional irrigation, while the other group was fully rainfall dependent. The rainfall dependent group had a lower crop water productivity, related to the uncertain timing of rainfall throughout the season.

Development and demonstration

Spatial prediction of soil water

Emma Leonard**Dryland croppers could soon take advantage of technology developed for irrigators, to understand variation in soil water availability across a paddock.***Photo: Emma Leonard*

Research trials have confirmed that a large proportion of yield variation relates to differences in soil properties, especially those linked to the storage and release of plant water. Moisture sensors have been providing a point source measurement of soil moisture but this does not indicate changes in availability across the landscape.

At the SPAA Conference in September 2011, Dr John Hornbuckle, CSIRO, indicated that it is now possible to spatially predict soil water availability across large areas and in rain-fed not just irrigated situations. Precision Ag News contacted Dr Hornbuckle to learn more.

Is it now possible to map available soil water?

Currently soil water availability to rooting depth cannot be measured directly through satellite images, but we can use these images with water inputs (irrigation or rainfall data) to create a water balance and track variable soil moisture deficit across a paddock. Soil moisture probes provide a way to calibrate against known data, but are not essential in this process.

The CSIRO research team has applied this approach using a

system called 'IrrisAT' to support irrigation scheduling and track real-time crop water use on a daily basis at a 30m resolution. This technology determines actual plant evapotranspiration, which is an indication of how much water the plant has extracted out of the soil in a day. By combining the water removal with water input data we can track soil moisture deficit spatially across an area, in real-time throughout a crop's growing cycle.

What data is required to map soil water deficit?

From the Bureau of Meteorology we source reference evapotranspiration data. Information on crop stress is gathered from satellite imagery. By combining these two sources of information we can infer water availability.

For IrrisAT we have been using satellite imagery from both MODIS and Landsat. The red, near infrared and thermal bands are used to determine crop stress. This combination of evapotranspiration and satellite data has been used successfully to track soil water deficit for scheduling irrigation.

A similar approach could be used in rain-fed systems. The main difference is there is likely to be more

crop stress in the rain-fed system, hence the value of the thermal band which now gathered from the satellite data to provide an indication of crop stress.

What further research is required to establish a commercial tool/service?

We need to run further trials to fine-tune the technology to end-users' needs and to specific crops in dryland situations. An applied research trial in which we could work with a group of growers to fine-tune the relationships with crop stress is all that is required. Plus the packaging of the information into a decision support tool.

Currently we are working with stressed crops in irrigated wine grape production and have also looked at some dryland cotton crops.

Not having to deal with irrigation actually makes the process easier. Measuring irrigation applications spatially across fields in surface systems is difficult to do accurately and affects the water balance calculations and hence calculated soil moisture deficits. In rain-fed systems this issue is removed.

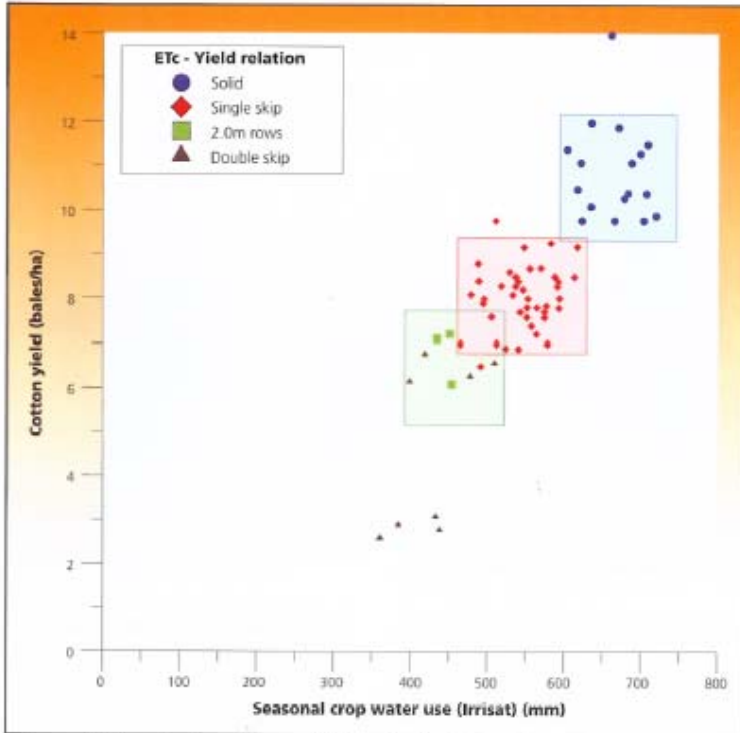


Figure 1. The relationship established using IrrisAT between cotton yield and seasonal water use between different row configurations.

Development and demonstration

What else can IrrisAT offer?

One element of the IrrisAT system which growers have really been interested in is the benchmarking of crop yield and seasonal water use.

During 2011, IrrisAT was applied across 30,000ha of cotton in the Gwydir Valley of NSW over a range of row configurations and irrigation systems. One of the interesting findings was the ability to benchmark the effects of these configurations on crop yield (Figure 1).

Many growers were also surprised by how much variation they had between fields and also the effects of management on crop water use and associated yields. Many could relate these effects back to management practices including tillage and laser levelling.

Details: Dr John Hornbuckle,
CSIRO Land and Water,
0429 862 920,
john.hornbuckle@csiro.au



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Water Matters

Determining crop water use with IriSAT

By Janelle Montgomery (NSWDPI), John Hornbuckle (CSIRO) and Richard Soppe (CSIRO)

Following two seasons of successful trials with a new technology called IriSAT developed by CSIRO, 10 cotton consultants and 25 irrigators have signed up over 75,000 hectares of cotton for the 2011–12 trial. This year the trial in irrigated cotton has been expanded to include cotton in the Border Rivers, Gwydir and Namoi valleys.



Richard Soppe, Irrigation Research Scientist, CSIRO, prepares for a busy season with over 75,000 hectares of irrigated cotton signed up for the 2011–12 IriSAT trial.

IriSAT is a weather based irrigation scheduling service. The IriSAT service involves the installation of a network of two to four weather stations across the area so reliable local estimates of reference evapotranspiration (ET_o) can be obtained. It also uses satellite imagery to determine crop coefficients (K_c) that are site specific for individual irrigation fields which are then combined with ET_o to calculate crop water use (see insert). IriSAT provides customised irrigation scheduling information which is sent to irrigators via the web.

Usual practice is to obtain ET_o from the Bureau of Meteorology or SILO which is modelled regional data, and the K_c is a book value usually determined using overseas

data. IriSAT provides crop water use (ET_c) on a daily basis throughout the season based on local weather data and site-specific crop coefficients (K_c) (Figure 1).

IriSAT uses a web interface which was developed using Google maps and allows consultants to easily monitor multiple farms and fields. Irrigators have to upload three pieces of irrigation information:

- Irrigation date;
- Amount of irrigation water applied; and,
- Daily rainfall.

Over the past couple of seasons, CSIRO has made significant improvements to ensure information can be easily and quickly uploaded.

Figure 2 shows the water use and benchmarking data

FIGURE 2: Benchmarking yield and crop water use data from the Gwydir region developed from the IriSAT trial during the 2010–11 season showing effects of row configurations, irrigation systems and irrigation management strategies

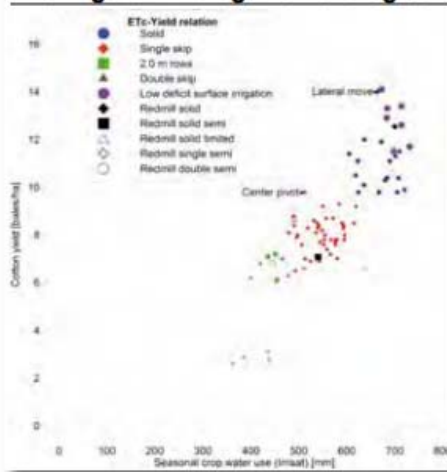
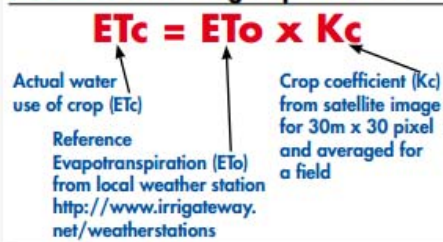


FIGURE 1: Calculating crop water use



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Water Matters

derived from the 2010–11 trial conducted in the Gwydir Valley. It includes data collected from the Gwydir Valley Irrigators Association row configuration trial conducted at Redmill, Moree. It provides a regional snapshot of the performance of row configurations, irrigation systems and irrigation deficit management strategies which can clearly be seen to affect yield and water use efficiency performance.

Many consultants and irrigators are extremely interested in the use of IrriSAT for developing benchmarking data as it measures actual crop water use (ETc) on individual fields.

John Norman, Norman Farms, Toobeah, has signed up all his cotton this season. "I'm really excited about the technology and using it for irrigation benchmarking," he says. "Measuring crop water use across my whole farm allows me to compare the efficiency of individual fields. IrriSAT measures what water actually goes through the plant, there is no guessing so it gives an accurate measure of crop water use."

The IrriSAT technology can also be used for the following:

- **Determining seasonal and daily crop water use.** The red line in Figure 3 shows the cumulative crop water use over the season. Daily crop water use information can also be downloaded from the website.

FIGURE 3: Water balance graph for an individual irrigation field

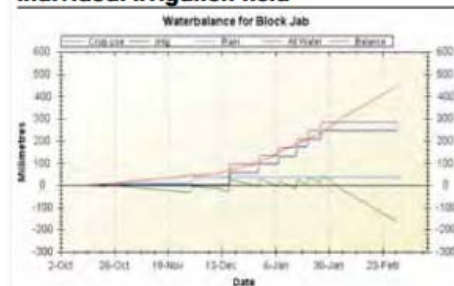


FIGURE 4: Variation in crop coefficient across fields and farm



- **Forecast of daily crop water use.** IrriSAT not only provides daily crop water use, but also predicts crop water use for the coming seven days. This is very useful information to help with scheduling decisions. Ultimately, this technology could be integrated with soil moisture monitoring software.
- **Looking back retrospectively at irrigation management.** Nick Gillingham, Keytah, Moree said "It was pretty handy looking back at the IrriSAT data at the end of the season. There was a good correlation between field yields and water use. We could look at the data and discuss why this correlation was occurring eg. did the paddock require laser levelling, was it the last block to be irrigated, compaction issues? It was a good check of what we had hypothesised."
- **Examine spatial variability across a field or multiple paddocks over a region.** The crop coefficient (Kc) map (Figure 4) shows the variability in the paddock, different stages of crop growth, impacts of waterlogging, insect pressures, nutrition, etc.
- **Benchmarking Crop Water Use across a farm and region.** IrriSAT provides seasonal crop water use (ETc) which is needed to calculate the crop water use index (CWUI)

$$\text{CWUI (kg/mm/ha)} = \frac{\text{lint yield (kg/ha)}}{\text{seasonal ETc (mm)}}$$

Rob Holmes, HMAg, says "The greatest use I have for IrriSAT ETc information is for benchmarking my clients' cotton crops. When I'm calculating the crop water use index I need a reliable estimate of ETc. The IrriSAT technology has provided me with this. It's quick and easily obtained for my end of season benchmarks. It reflects the whole paddock, rather than just a single square metre of the paddock. Benchmarking crop water use allows me to look back over the season with my clients and compare crop productivity in terms of water use between fields and farms. We can discuss what might be occurring in-field and try to improve over time."

- **IrriSAT as an in-season yield prediction tool.** Figure 2 shows a strong overall relationship between ETc and yield. There are clear thresholds in yield and seasonal crop water use for the different planting configurations. This initial assessment provides confidence that, with further refinement, IrriSAT could be used to provide an indication of yield potential for the current cotton crop, later in the irrigation season.

Further information on IrriSAT is available from:

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Rod Jackson, NSW DPI, Narrabri.
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Richard Soppe, CSIRO, Griffith.
E: Richard.Soppe@csiro.au Mob: 0457 536 913.

The authors would like to gratefully acknowledge the assistance provided by CRDC in funding this research and the consultants and growers who are participating in the IrriSAT trial.

NSW extends the mango season

TWO new mango varieties are under development for the small but dynamic NSW mango industry.

"The varieties, selected from a Queensland breeding trial for their suitability to the cooler climate in NSW, are receiving a high level of interest from local growers," said NSW DPI tropical horticulture industry leader Mark Hickey.

"The flavour and appearance of these new selections is very encouraging.

"Some of our NSW growers are keen to get growing material for evaluation in their orchards – when it becomes available."

Mr Hickey said the most common variety in Australia and in NSW was Kensington Pride, also known as Bowen, but newer varieties such as Calypso and HoneyGold are proving popular.

"With the mango harvest underway in NSW, varietal performance is a talking point among growers.

"The Northern NSW crop is once again patchy this season, with Kensington Pride crops failing on most farms, and variable reports on performance of other varieties.

"Calypso and HoneyGold have once again proven more reliable than KP, even with the cool start

to the season and wet spring."

Mr Hickey said the North Coast mango industry extends the growing season and the availability of fruit.

"While most mangoes are grown commercially in the Northern Territory, Queensland and Western Australia, NSW is a small but important player.

"You might say NSW growers provide the last chance each season for Australians to have a mango.

"Everybody thinks once Christmas is over, so are the mangoes.

"But NSW is giving people an opportunity after Australia Day and onwards."

Growers from South East Queensland, the Coffs Harbour regions and the NSW Northern Rivers met last month at the NSW DPI Centre for Tropical Horticulture at Alstonville for a workshop and farmwalk.

"The prevalence of fungal disease as a result of the recent wet weather has focused growers' attention on better disease management," Mr Hickey said.

"Speakers at the field day emphasised the importance of maintaining orchard hygiene, by removing infected wood and prunings from the orchard, effectively reducing the inoculum levels in the orchard."

Walgett improves water

SATELLITE technology is on trial for its capacity to help irrigators in northern NSW monitor crop water use.

IrriSAT technology is a web-based system that uses both satellite images and local weather data to monitor crop water use.

The technology can also be used to detect in field crop growth variability during the season and conduct end of season benchmarking to compare water use between fields.

IrriSAT's ability to function as a yield prediction tool is also being explored in the trial, by irrigation officers from NSW DPI and CSIRO Land and Water.

Funding for the project is being provided by the Cotton Research Development Corporation.

Irrigators' interest in the technology has grown rapidly since it was first trialled with cotton growers three years ago, thanks to extension activities by NSW DPI officers Janelle Montgomery, Rod Jackson and Tim Weaver.

The cotton area being monitored in northern NSW has increased five-fold from 20,000 hectares in 2010-11 to 100,000ha in 2011-12.

This season NSW DPI invited members of the Walgett Cotton Growers' Association (CGA) to participate in the IrriSAT trial.

While Walgett has sustained two floods in the past six months and some of the best rainfall in decades, drought and zero water allocations in the preceding seven years made irrigators determined to look for new ways to save water and increase water use efficiency.

"It would be great for them to bench-



Irrigators James Moore and Toby Moore with Agronomist Lori Nemecek (centre) and the new weather station located at "Walma".

mark against other irrigators so they could then improve or change their strategies," said president of Walgett CGA and local irrigator Toby Moore.

John Norman, Norman Farms, Toobeah, was another who signed up all his cotton this season.

"Measuring crop water use across my whole farm allows me to compare the efficiency of individual fields," Mr Norman said.

"IrriSAT measures what water actually goes through the plant, there is no guessing, so it gives an accurate measure of crop water use."

To help Walgett CGA participate in the trial, NSW DPI also assisted their application to Cotton Australia to fund a weather station capable of measuring and relaying real time weather information.


Decisions relating to further trials or possible commercialisation of the technology to industry will be made at the end of the 2011-12 cotton season.

■ Contact Tim Weaver, Walgett, 0499 069 277, tim.weaver@dpi.nsw.gov.au, Rod Jackson, Narrabri, (02) 6799 1537, rod.jackson@dpi.nsw.gov.au

B. Have you developed any online resources and what is the website address?

We now have online real-time measured reference evapotranspiration for the Keytah and Weemalah stations that were installed in the Gwydir and the Walgett weather station in the Namoi. This information is freely available on the net and can be accessed from <http://weather.irrigateway.net/aws/index.php>

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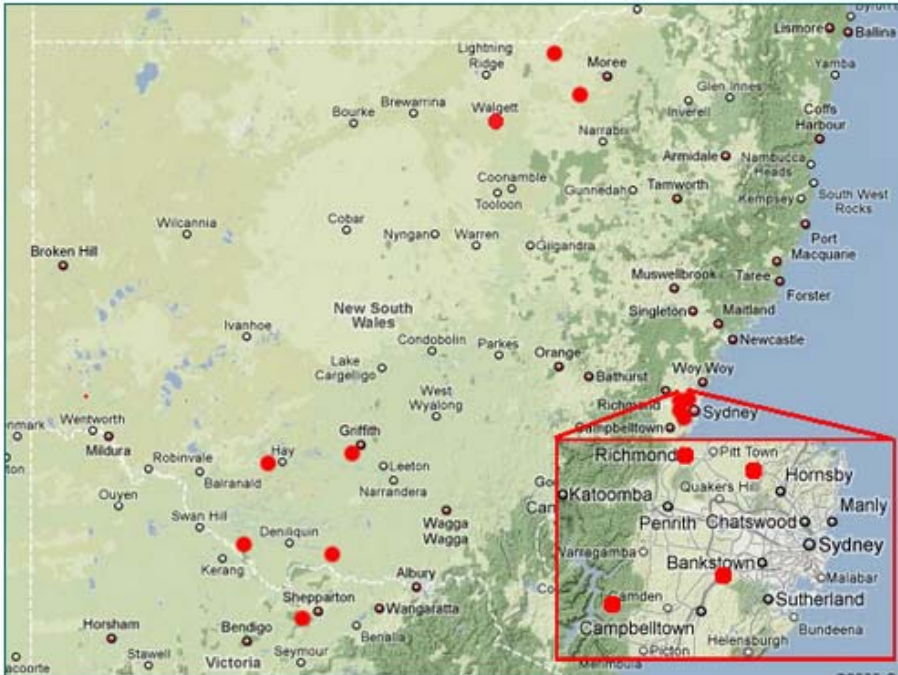
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Lastest Hour's Average readings from all weatherstations
Time format: AEDT

Station Name	Latest reading	Air Temp (°C)	Rel. Humidity (%)	Wind Speed (km/hr)	Rain (mm)	Solar Rad (MJ/m ²)
Dural	13:00	15.62	89.5	5.52	0	0.18
Finley	13:00	20.3	29.32	14.18	0	3.03
Griffith	13:00	23.23	36.46	12.27	0	3.16
Hay	13:00	20.91	33.7	22.2	0	2.84
Keytah	17:00	36.52	10.32	20.67	0	1.77
Leppington	13:00	17.18	79.75	2.83	0	0.28
Oakdale	13:00	14.3	94.1	2	0	0.45
Richmond	13:00	16.23	90	6.05	0.2	0.24
Tatura	13:00	18.1	38.24	20.78	0	3.09
Tullakool	13:00	19.35	35.75	16.52	0	3.77
Walgett	13:00	31.6	14.72	15.17	0	2.82
Weemalah	12:00	31.78	18.98	20.56	0	0.66

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Also included is a 7 day reference evapotranspiration forecast that was developed in the project for each of these stations. This forecasting service was developed using the 7 day Operational Consensus Forecasts provided by the Bureau of Meteorology <http://www.bom.gov.au/catalogue/data-feeds.shtml>. This raw forecast data (Temp, Humidity, Wind Speed etc) has been converted into a 7 day ETo forecast by CSIRO which was used in IrrisAT to forecast water needs 7 days in advance. Current forecast data is available on the

Irrigateway website for each of the regions where IrrisAT is being implemented, see http://weather.irrigateway.net/?aws_id=6&view=7dayforecast . This ETo forecasting system provided the basis for the ETo feeds into the IrrisAT system on a daily basis. This information is freely available and the website can also be used to download historical data from these weather stations.

The screenshot shows the Irrigateway website interface. The header includes the 'irrigateway' logo and the CSIRO logo. A navigation menu contains links for Home, Tools, Publications, Projects, Weatherstations, About, and Contact. The main content area is titled 'irrigateway Weatherstations' and features a sidebar with a list of weather stations categorized by region: Riverina (Griffith, Hay, Finley, Tullakool), Hawkesbury-Nepean (Richmond, Dural, Leppington, Oakdale), Gwydir (Keytah, Weemalah), Namoi (Walgett), and Murray (Tatura). The 'Weemalah' station is selected, and its '7 Day forecast data for Moree' is displayed in a table. The table has three columns: Date, ET-ref (short) mm, and ET-ref (tall) mm. The data rows are as follows:

Date	ET-ref (short) mm	ET-ref (tall) mm
Fri 16/11	5.2	5.3
Sat 17/11	5.3	6.1
Sun 18/11	3.6	3.9
Mon 19/11	8.1	11.2
Tue 20/11	5.8	7
Wed 21/11	5.7	6.9
Thu 22/11	6.4	6.8

The footer of the page also contains the navigation menu: Home | Tools | Publications | Projects | Weatherstations | About | Contact.

General updates to the irrigateway website (www.irrigateway.net) have also been undertaken to include spatial data presentation for irrigators fields.