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SMARTER IRRIGATION SCHEDULING IN THE SUGARCANE FARMING SYSTEM USING THE INTERNET OF THINGS

E. Wang, S. Attard, M. Mcglinchey, W. Xiang, B. Philippa, A. Linton and Y. Everingham

Abstract Better irrigation practices can lead to improved yields through less water stress and reduced water usage to deliver economic benefits for farmers. More and more sugarcane growers are transitioning to automated irrigation in the Burdekin and other regions. Automated irrigation systems can save farmers a significant amount of time by remotely turning on and off pumps and valves. However, the system could be improved if it could be integrated with tools that factor in the weather, crop growing conditions, water deficit, and crop stress, to improve irrigation use efficiency. IrrigWeb is a decision support tool that is turned to as a solution to this problem. IrrigWeb uses CANEGRO to help farmers decide when to irrigate and how much to apply. Farmers can then use this information to plan their irrigation management. However, managing irrigation is a considerable time investment for Burdekin farmers. A tool is needed to integrate the auto-irrigation system (e.g., WiSA) and IrrigWeb to provide a smarter irrigation solution. An uplink program (WiSA to IrrigWeb) has been successfully developed and implemented as part of a pilot study. It saves farmers a significant amount of time by uploading irrigation and rainfall data automatically instead of the farmer having to input them manually. This paper focuses on developing a smarter irrigation scheduling tool that connects IrrigWeb to WiSA. A downlink program was developed to download, calculate and apply irrigation schedules automatically. In this process, sugarcane irrigators will spend less time manually setting up irrigation schedules as it will happen automatically. The simulation results demonstrated that the downlink program could improve the scheduling by incorporating practical limitations, such as pumping capacity or pumping time constraints, that are found on the farm.

Key words Internet of Things, Smart irrigation, Sugarcane farming

INTRODUCTION

The revised Burdekin water quality improvement plan aspires to achieve an 80% reduction in dissolved inorganic nitrogen (DIN) (NQ Dry Tropics, 2016). Because of the strong linkage between irrigation management and DIN losses, managing DIN must involve both managing the N rate that is applied, and irrigation after that. Irrigation management and scheduling are both tedious and time-consuming for many sugarcane farmers, due to the need to irrigate almost all year round in the Burdekin region. Better irrigation practices can lead to improved yields through less water stress, by matching irrigation to crop water needs.

The Internet of Things (IoT) aims to connect physical objects - “things” to the Internet, and thus creates opportunities for more direct integration between the physical world and computer-based systems. IoT is becoming all-encompassing with smart cities, homes, grid, transportation and agriculture (Atzori et al., 2010). In agriculture, IoT is capable of offering many solutions to the modernisation of farming practices and empowering farmers to deal with the challenges they face (Ryu et al., 2015).

Combining the technologies of radio telemetry, solar power and personal computers, the IoT-based automated irrigation system can reduce water use and labour while improving crop quality and quantity (Gillies et al., 2017). More and more sugarcane growers in the Burdekin region are transitioning to this solution. The automated irrigation system allows farmers to remotely turn on and off pumps and valves, which can save them a substantial amount of time, water and energy. However, farmers still have to spend a significant amount of time in setting up irrigation schedules, since the automated irrigation system is not able to automatically determine the right amount of water to apply, which is also one of the most tedious, time-consuming and difficult parts in irrigation management. Moreover, without the consideration of field characteristics, crop class, crop start dates, soil characteristics and weather information, the system cannot provide the optimised irrigation schedule, which could raise the chance of maximising crop yield.

Decision support tools, such as IrrigWeb, can address the "blind spot" in existing automation technologies. IrrigWeb is a web-based sugarcane crop model that uses CANEGRO (Inman-Bamber and McGlinchey, 2003) to provide farmers with current and local advice on sugarcane development and water use for their specific fields. In terms of irrigation management, IrrigWeb can help farmers decide when to irrigate and how much to apply. Farmers then calculate the irrigation schedules for each irrigation set based on their hydraulic group setup, energy and water constraints, and other factors. In typical years, a typical Burdekin irrigation set would receive between 15 – 20 irrigation events/year; which amounts to 300 – 400 irrigation events for a farm with 20 sets. It is a considerable time commitment to set up daily irrigation schedules.

A tool is needed to enhance irrigation use efficiency in a way that is convenient to the farmer. The Internet of Things can do this by integrating WiSA, the current existing auto-irrigation system and IrrigWeb. As part of a pilot study, an uplink program that connects WiSA to IrrigWeb has been successfully developed and implemented in one Burdekin sugarcane farm (Wang et al., 2018). The uplink program was designed to reduce the amount of time farmers need to invest in manually entering irrigation records. The uplink program has been running smoothly on the farm since August 2017. During the first 12-month period, 1153 irrigation events for the 15 paddocks and 119 rainfall events were recorded by the automated irrigation system and automatically uploaded into IrrigWeb. If we assume it takes an average of 3 minutes to upload each record, a total of 64 hours has been saved with the help of the uplink program. Another benefit is that the farmer can now see the exact amount being applied to each paddock and make modifications to his irrigation management if they are required.

To complete the two-way communication channel, a downlink program is needed to transfer information from IrrigWeb to WiSA. A downlink program was developed to download, extract, calculate and apply irrigation schedules automatically. Using the soil water deficit, crop water use, water runoff, deep drainage data from IrrigWeb, the downlink program can determine irrigation priorities and calculate irrigation water amounts for each irrigation set. The downlink program also takes consideration of irrigation preferences, energy constraint, hydraulic group setup, pump capacity and irrigation set characteristics in setting up irrigation schedules. A computer simulation was carried out using data from the 2018 harvest year of one Burdekin sugarcane farm. The downlink generated schedule was nearly identical to the IrrigWeb generated schedule.

SMARTER IRRIGATION SYSTEM

The architecture of the proposed IoT-enabled smarter irrigation management system is shown in Figure 1. It consists of three stages:

1) Stage 1 – auto-irrigation management: an uplink program (WiSA to IrrigWeb) automatically extracts, calculates and uploads the irrigation and rainfall data from WiSA to IrrigWeb;

2) Stage 2 – improving irrigation scheduling: a downlink program (IrrigWeb to WiSA) automatically downloads, calculates and applies the optimised irrigation schedule from IrrigWeb to WiSA; and

3) Stage 3 – smarter irrigation system based on IoT: extra sensor data will be fed into the smarter irrigation system to improve the robustness of the system and precision of the irrigation schedule, which will ultimately make smarter irrigation fully autonomous.

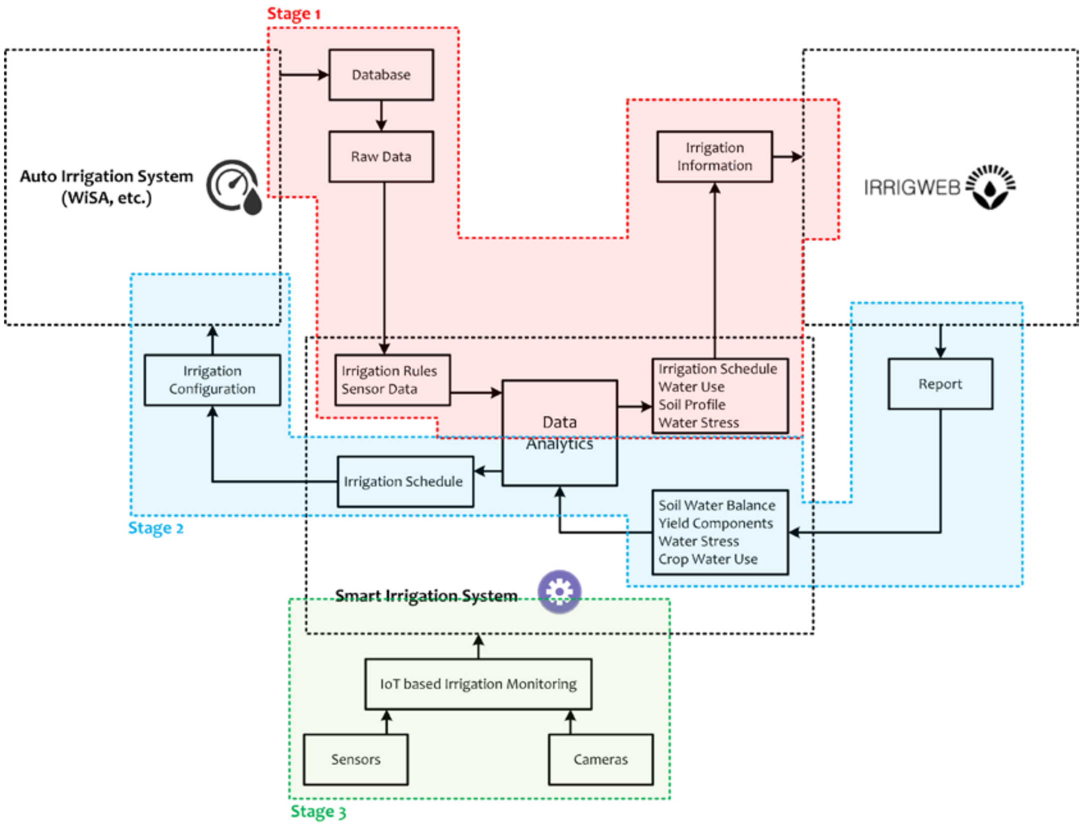

Figure 1*.* Smarter irrigation management system.

DOWNLINK PROGRAM

IrrigWeb is a decision support tool for the sugar industry. IrrigWeb uses CANEGRO to provide farmers with current and local advice on sugarcane development and water use for their specific fields. The tool combines crop water use estimates with user-defined irrigation system constraints and crop cycle inputs to schedule future irrigation events. At the initialisation stage, the user must put in farm information, such as area, ratoon, soil type, row configuration, irrigation management rule, irrigation deficit and harvest date. IrrigWeb acquires meteorological data daily from a 3rd party source such as the Queensland Government's SILO application, along with the weather data from local weather stations, and use CANEGRO model to calculate crop growth information, such as daily soil water deficit, crop water use, crop stress, biomass. As for irrigation, IrrigWeb uses soil water deficit and estimated crop water use to provide the amount of water required for each irrigation set. Farmers can then use this information to plan their irrigation management and apply irrigation schedules to their automated irrigation tools. IrrigWeb can also provide graphical and tabular reports on crop development, including crop stress factor, biomass and yields

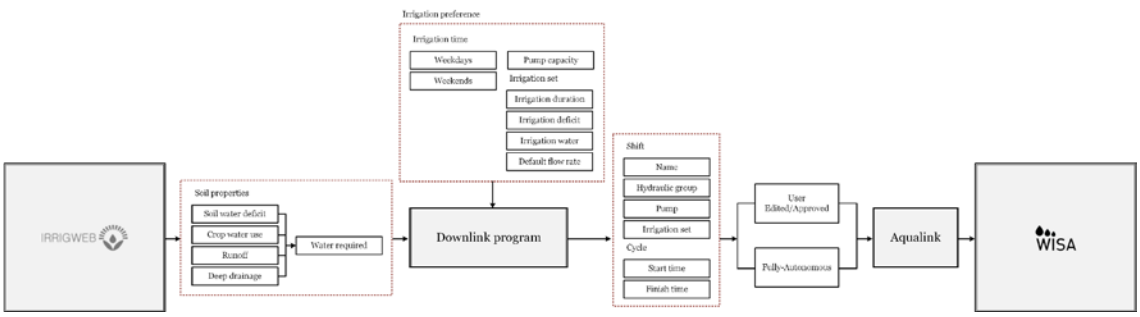

Figure 2*.* Downlink program.

The downlink program aims to acquire soil water properties from IrrigWeb and to calculate irrigation water amounts and schedules for each irrigation set. The system diagram of the downlink program is shown in Figure 2. As depicted in the figure, the downlink program:

1. Interrogates the IrrigWeb sever hourly and downloads the soil water properties for each irrigation set, including soil water deficit (SWD), crop water use (CWU), runoff (RO) and deep drainage (DD);

2. Combines irrigation time preferences (e.g., off-peak and peak time for weekdays and weekends), pump capacities for each hydraulic group, irrigation characteristics for each set (including duration, SWD deficit threshold, default design flow rate);

3. Calculates daily SWDs for each irrigation set using the following formula:

$$SWD_{\text{of today}} = (SWD + I + Rainfall - CWU - DD - RO)_{\text{of yesterday}};$$

where I = irrigation applied

4. Determines the irrigation priority ranking based on the calculated SWD;

5. Uses the following formula to calculate the irrigation applied (I) required if the SWD of an irrigation set passes below the user-defined irrigation deficit threshold (TH):

$$I_{\text{of today}}\ (mm) = TH - SWD_{\text{of today}},$$

if SWD of today < TH.

6. Calculates the irrigation duration for each set based on the obtained I required;

7. Calculates irrigation schedule for each irrigation set based on the irrigation time preference, the pump capacity and the irrigation priority ranking;

8. Exports the irrigation schedule configuration in the format of the automated irrigation system, e.g., irrigation shifts and cycles for WiSA;

9. Updates irrigation schedule in the automated irrigation system and starts a new irrigation schedule.

RESULTS

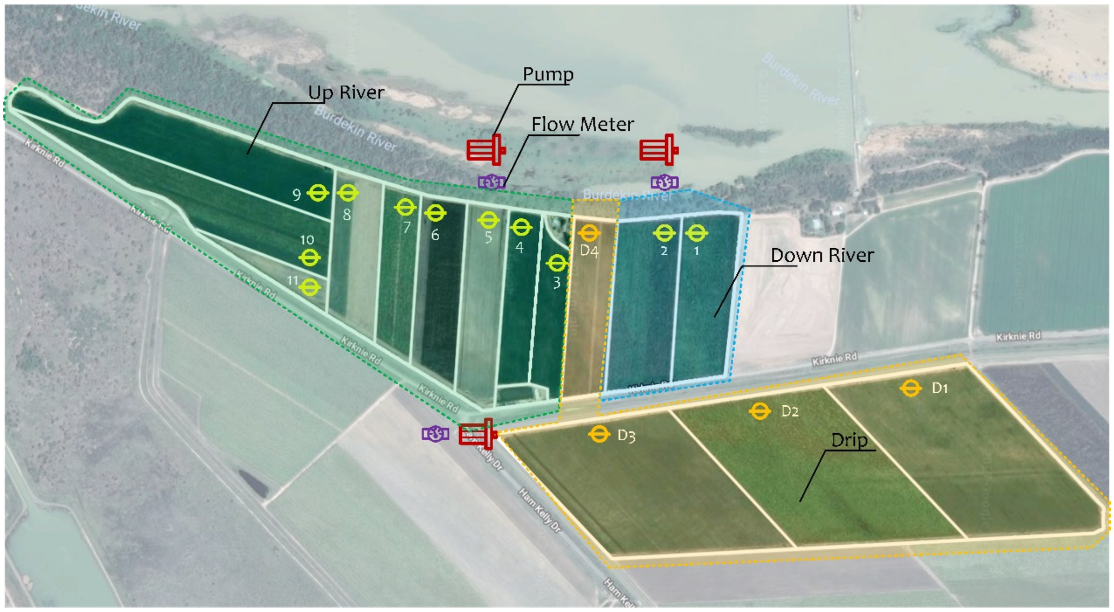

Figure 3. The Test farm is divided into three hydraulic groups. Valves 1 and 2 are supplied by the down-river pump; Valves 3 – 11 are supplied by the up-river pump; while the 4 drip fields, D1 – D4 are supplied by the third pump.

The sugarcane farm setup used to test the downlink program is shown in Figure 3. This Burdekin sugarcane farm is located near Home Hill. It is around 100 ha in size, and its irrigation system is a combination of both pressurised (drip) and furrow irrigation. As shown in the figure, the 15 paddocks in this farm are divided into three hydraulic groups, with 11 paddocks using furrow irrigation, i.e., the down-river hydraulic group with 2 paddocks, and the up-river hydraulic group with 9 paddocks, and 4 paddocks using pressurised (drip) irrigation. The test farm has been using WiSA automated system for more than six years. The data of this farm including daily soil water deficit, irrigation, crop water use, rainfall and yield, in the 2018 harvest year is used for running the downlink program scheduling simulation.

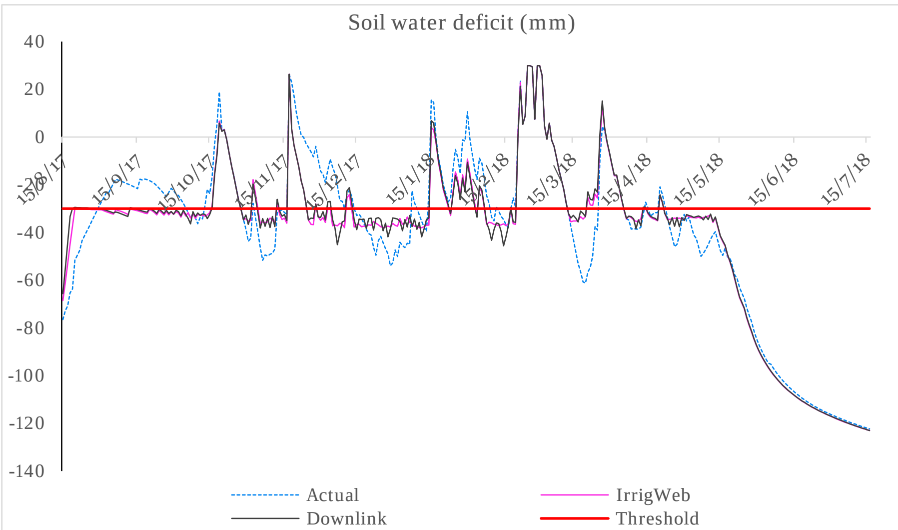

Figure 4. Soil water deficit comparison among actual, downlink and IrrigWeb schedules for D1.

Figure 4 shows the SWD, yield and water use comparison of the actual (i.e. what the farmer applied), downlink and IrrigWeb schedules for D1 drip irrigation set. As can be seen from the figure, the SWD curve of the downlink program is nearly identical to the one of IrrigWeb. Since drip irrigation is the most efficient irrigation method and the farmer has managed his irrigation for this drip block well, the crop development results of the three are nearly identical.

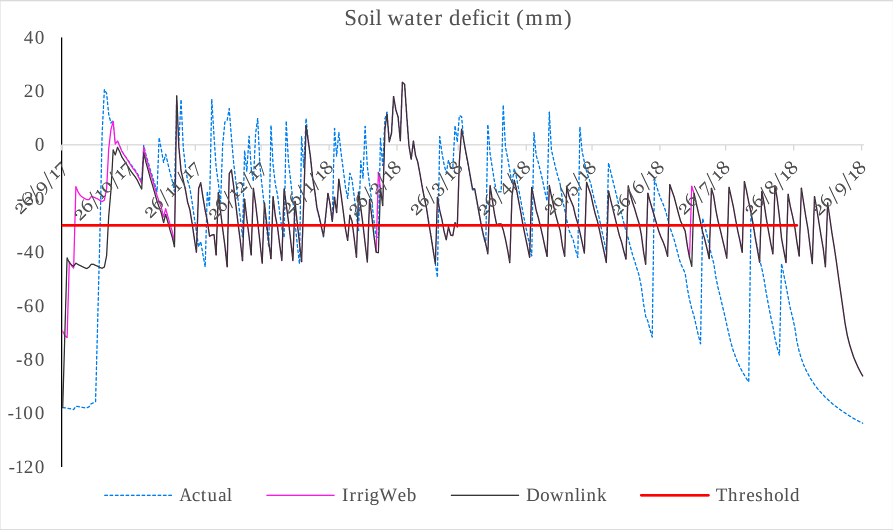

Figure 5*.* Soil water deficit comparison among actual, downlink and IrrigWeb schedules for Set 2 in the down-river hydraulic group.

Figure 5 shows the SWD, yield and water use comparison of the actual, downlink and IrrigWeb schedules for Set 2, a furrow irrigated field in the down-river hydraulic group. The downlink program can achieve close results in SWD to IrrigWeb. On the other hand, it can be observed from the SWD curve that the actual (farmer management) differs from IrrigWeb and downlink during the last 3 months before the harvesting. Around this time, the yield expected by the farmer's management begins to deviate from the higher yields expected by IrrigWeb and downlink. The difference between the actual irrigation used and that predicted by IrrigWeb and downlink, suggest there may be opportunities to reduce irrigation application and costs while increasing efficiency.

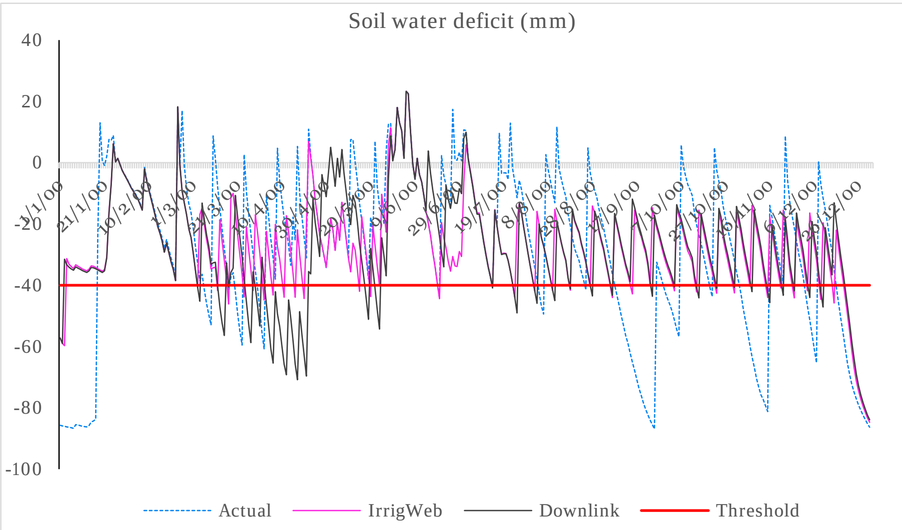

Figure 6*.* Soil water deficit comparison among actual, downlink and IrrigWeb schedules for Set 2 in the down-river hydraulic group.

Figure 6 shows the SWD, yield and water use comparison of the actual, downlink and IrrigWeb schedules for Set 8, a furrow irrigated field in the up-river hydraulic group. The SWD curve of the downlink program has a drop around 20/03/2018, compared to the IrrigWeb SWD curve. This is due to the following reasons.

There was a large rainfall event on 13/03/2018, and all the irrigation sets in this hydraulic group developed a full soil profile and were at field capacity. Therefore, by the 20/03/18 all 9 irrigation sets have a similar SWD and are approaching the irrigation deficit threshold at a very similar rate. There is a huge irrigation demand for all the 9 irrigation sets in this hydraulic group on 20/03/2018. Due to the limitation of the pump capacity, the large number of irrigation sets in this group and the energy constraint (Tariff 62 for this farmer, with 10-hour off-peak time in weekdays), and also the large crop water use during the period, the requirement to irrigate all 9 sets on the same day cannot be fulfilled. Downlink then creates a schedule that prioritises fields according to irrigation availability. In this situation, Set 8 was not able to be irrigated at the optimum time (i.e. when the irrigation deficit threshold was reached). Therefore, the inadequate irrigation for this set resulted in some crop stresses, which was also observed for some other irrigation sets in this hydraulic group. However, the water balance was improved after a short period. IrrigWeb calculates a potential yield and does not take into consideration the limitation of pumping capacity. The difference between actual irrigation applied and predicted usage offers opportunities to examine where improvements could be made.

CONCLUSION

The project aims to develop a smarter irrigation system to improve irrigation management and scheduling in sugarcane farming. The first stage of the project has shown a significant benefit in time-saving to farmers. In the second stage of this project, a downlink program was developed to connect IrrigWeb to WiSA, which can download, extract, calculate and apply irrigation schedules automatically. Downlink successfully mimics the IrrigWeb generated soil water deficit for all fields. Downlink improves the scheduling by incorporating practical limitations, such as pumping capacity or pumping time constraints, that are found on the farm. The Downlink generated schedule is more life-like and realistic than the IrrigWeb generated a schedule. The simulation results demonstrated the potential for significant economic benefits to the farmer in yield increase and water and energy saving. Combing the *uplink* and *downlink* programs, a smarter irrigation management system can automatically control sugarcane irrigation, improve production and reduce water use, eventually reduce runoff and improve GBR water quality.

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