Introduction

Evidence indicates that Weather-Based Irrigation Controllers (WBICs) are effective tools for optimizing irrigation water consumption. WBICs are promoted by the United States Environmental Protection Agency as a tool for water conservation for commercial and residential settings. This research infers that these controllers can be used as cost-effective tools for optimizing water delivery systems for agricultural in the Least Developed countries. This case study illustrates the efficacy of WBICs as proposed for use in the City of Camarillo in the Camrosa Irrigation District in California in the United States and suggests that similar outcomes and measures of water-use efficiency can be replicated. The WBIC under study is the Weathermatic Smartline® controller which is a stand-alone or cloud-based system appropriate for all scales. The Smartline® unit is also capable of being powered as a 12vDC unit by solar batteries.

This weather-based controller in this research also serves as a tool for management whose data and programming are fully managed by cellular communication. The data is stored in the Amazon "cloud" and provides real time management.

Goals and Objectives

Irrigating by daily evapotranspiration adjustments has been shown to be an effective tool in optimizing water for irrigation use. Figure 1 compares irrigation scheduling alternatives in inches of water applied. The Figure illustrates the standard, default practice of irrigating the same amount each day, the change in irrigation water use when weekly adjustments are made and the change when daily adjustments are made.

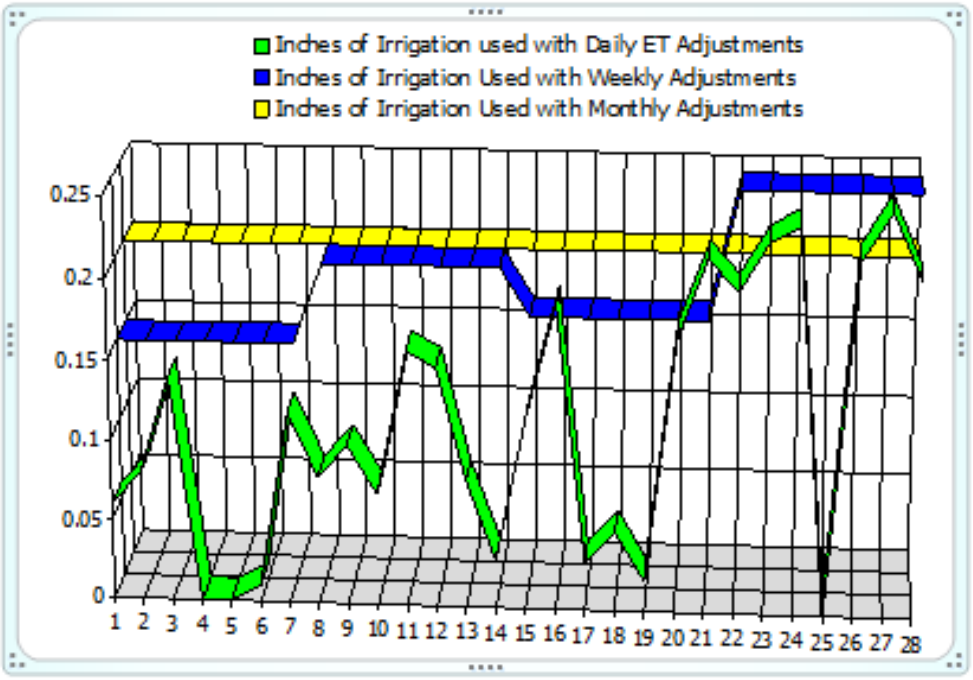

Figure 1 Comparison of irrigation scheduling alternatives in inches of water

The goal of using a WBIC in the City of Camarillo in the Camrosa Irrigation District was to apply water more efficiently in the park system. Prior to the installation of the Smartline® controllers, the users were watering their parks by a pre-set time each day. Additionally, the City wanted to monitor, control and program all their units by cloud technology and to generate reports of irrigation use by downloading data by cloud-based technology.

The objective of the study was to compare the overall consumption of the parks when the WBICs were programmed and allowed to run for one year, with an additional 10% reduction, with an additional 15% reduction and with an additional 20% reduction.

It is important to note that the City of Camarillo had already reduced its watering times by 30% on average in all its parks due to a mandate set by the State of California to reduce outdoor watering by at least 25%. The City of Camarillo wanted to find ways of reducing its water an additional 15-20% in order to provide water to a developer who wanted to build multi-family homes in the city. The City contracted an irrigation consultant to estimate savings by the WBIC.

Methods

One controller was installed at each park site in place of the standard, non-WBIC unit. The new controllers were the Weathermatic Smartline® controllers. Below is a description of how the controllers operate.

First, the controller utilizes Hargreaves's formula to calculate evapotranspiration (ET_o) and then multiplies this value by the crop coefficient to determine the water requirements for each zone on a daily basis.

Hargreaves formula is given by:

$ET_o = a + b.\frac{1}{\lambda}.0.0023.\{\frac{T\max + Tmin}{2} + 17.8\}.\sqrt{Tmax - Tmin}\,.Ra$, where

T max (^{0}C) is the maximum daily air temperature,

T min (^{0}C) is the minimum daily air temperature

Ra (MJ m-2 d-1) is the extra-terrestrial solar radiation.

The two only sensor required for this equation is a temperature sensor, which is situated in a plastic housing the approximate size of a soft-drink can, and connected to an input port of the controller either by hard-wire or wirelessly. The sensor takes temperature readings every seven seconds and sends its aggregated data to the controller at 11:59 PM. Solar radiation in derived by the user inputting latitude and correct time, once only. There are no satellite or web site connections required for data input.

Second, the user inputs four data points for each irrigation zone: precipitation rate of the emission device; crop coefficient for the plant type and season; soil type; and slope. If there is an available flow sensor, the controller will accept flow data and record flows for each zone and will provide reports for any and all zones for any time period. Additionally, the controller, with user input, will assign minimum and maximum flows for each zone and turn off zones if high flows are registered and send notifications by email. There are an additional 15 "alerts" that are sent via email.

The irrigation schedule, start times and days of the week, are set by the user. The user can select not only times to irrigate but may omit times and days that irrigation is not permitted.

The zones, or valves, must be electrically connected to the controller but the power to operate the controller can be solar-based using a 12vDC rechargeable battery. The unit has an inverter so that 24vAC or 12vDC solenoids can be used. The controller is capable of controlling 1-99 valves.

In the case of the City of Camarillo, each controller was connected to a flow sensor and each controller was connected to its weather sensor wirelessly.

Results

The four options are displayed in Table 1.

Locations	Conservation Target (2013 less 32%)	CY 2015	2015 Reduction (AF) from 2013	2015 Reduction (%) from 2013	Acre Feet by WBIC with no deduction Option 1	Acre feet by WBIC with 10% reduction Option 2	Acre feet by WBIC with 15% reduction Option 3	Acre feet by WBIC with 20% reduction Option 4
PVPR	**72.59**	**79.06**	**27.68**	**26%**	**83.46**	**75.11**	**70.94**	**66.77**
Birchview	0.66	0.77	0.21	21%	0.71	0.64	0.60	0.57
Calleguas Creek	5.19	5.84	1.79	23%	6.51	5.86	5.53	5.21
Camarillo Grove	2.76	1.33	2.72	67%	4.58	4.12	3.89	3.66
Encanto	4.62	3.63	3.17	47%	6.11	5.50	5.19	4.89
Heritage	12.42	11.45	6.81	37%	14.25	12.83	12.11	11.40
Mission Oaks	29.06	34.10	8.64	20%	30.94	27.85	26.30	24.75
Quito	8.89	10.90	2.18	17%	9.57	8.61	8.13	7.66
Trailside	0.53	0.59	0.19	24%	0.61	0.55	0.52	0.49
Woodside	8.45	10.46	1.97	16%	10.18	9.16	8.65	8.14
ACHS	**48.78**	**48.90**	**22.83**	**32%**	**32.34**	**29.11**	**27.49**	**25.87**
PVSD	28.15	24.53	16.87	41%	**23.12**	**20.81**	**19.65**	**18.50**
Las Colinas	16.96	13.89	11.05	44%	13.79	12.41	11.72	11.03
Santa Rosa	10.33	9.52	5.67	37%	8.11	7.30	6.89	6.49
Tierra Linda	0.86	1.12	0.14	11%	1.22	1.10	1.04	0.98
TOTAL	**149.52**	**152.50**	**67.39**	**31%**	**138.92**	**125.03**	**118.08**	**111.14**
DIFFERENCE FROM TARGET (AF)					**10.60**	**24.49**	**31.44**	**38.39**
DIFFERENCE FROM TARGET (%)					**-8%**	**-20%**	**-27%**	**-35%**

Discussion

The WBIC, when configured at start-up and with no subsequent human intervention, resulted in an overall reduction in 8%, option 2 resulted in an overall savings of 20%; option 3 resulted in an overall savings of 37%; and option 4 resulted in an overall savings of 39%.

The challenge for the City of Camarillo was to achieve an additional 15-20% over the already implemented savings of 30%, which was mandated by the State of California.

Options 2,3 and 4 achieved their objectives.

Conclusion

The WBIC adjusts irrigation demand every day. If, as in the case of the City of Camarillo, they have water consumption goals and need to reduce by an additional amount of water, they can do so and still achieve satisfactory crop production. The important conclusion and "take-home" message from this research, is that a WBIC optimizes water use for irrigation and this tool can be replicated to any scale. The City was able to monitor use, make adjustments, and see immediate use while mitigating damage by line breaks remotely by using the optional cloud feature.