Producing more with less using retro-fit telemetry to reduce energy and water consumption during carrot production

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Abstract

Modification of new and existing technology in agriculture is required to ensure productivity growth and to address issues of climate change and natural resource sustainability. Two key challenges faced by the irrigated agriculture community are competition for increasingly limited water resources and increases in energy costs. Limitations to water availability are expected to intensify under probable climate change scenarios, while energy costs will increase under pricing strategies, including those to limit carbon emissions. Travelling gun irrigators are commonly used in Tasmania due to their low capital cost and practicality of use on undulating topography, but non-uniformity of water distribution of is of concern. Modifications to improve the performance of a travelling gun irrigator were made in a collaborative project involving retro-fitting telemetry devices and modified irrigation components to a travelling gun irrigator to enable a constant set pressure to be maintained at the gun regardless of slope or length of the irrigation run. Comparisons between modified and conventional travelling gun irrigation were conducted and included monitoring energy and water use, yield, quality and disease assessments in a carrot crop. Results show a 17% and 5% reduction in energy and water use respectively between the modified and conventional irrigator, for a 10% increase in yield of carrots for the modified irrigator. The retro-fitted component technology developed in this project demonstrate an innovative approach to address issues of sustainable natural resources management, adapting to climate change challenges and responding to increases in energy costs.

Key Words

Irrigation, telemetry, water use efficiency

Introduction

Irrigators face increasing economic, environmental and social challenges. Economic pressures resulting from fluctuating and increasing energy prices drive a preference for increased productivity through reduced input use e.g. water, energy use, or both. Sustainable management of natural resources is required to maintain and increase future food production to meet increasing global demand. Socially, irrigators are also under increasing pressure from other sectors to be more efficient and reduce the use of limited resources to enable redistribution of natural resources to other sectors e.g. urban or environmental use. As competition for natural resources increases, irrigators will require innovative solutions to adapt.

Significant contributions are made to the Australian economy by the irrigation industry. The largest water user in Australia is irrigated agriculture, which in 2009/2010 used 6,600 GL (50% of total Australian water usage). Irrigated vegetable production in Australia was valued at $2.6 billion in 2009/10, with 80% of vegetable producers in Australia using some type of irrigation (ABS 2011).

The average application rate in the Australian vegetable industry in 2009/2010 was 4.0 ML/ha, totalling 420,000 ML (ABS 2011). The gross value of the Tasmanian irrigated vegetables for human consumption and seed production in 2008/09 was $217m, from 115000 ha, 99% of which received some form of irrigation (ABS 2011). The annual volume applied in 2009/10 in Tasmania was 44,300 ML, averaging 3.0 ML/ha. Irrigation requirements for Tasmanian summer vegetable crops ranges between 2.5 to 5.5 ML/ha (O'Donnell, 2006).

Numerous challenges face the irrigation sector including a reduction in the amount of water available, extended drought conditions in many areas and government policy changes to reform water use and the water economy in Australia. Thus irrigated agriculture is under increased pressure to enhance irrigation practices for improved water use efficiency and productivity. Travelling gun irrigators are commonly used in the Tasmanian vegetable industry due to their low capital cost, ease of use on undulating topography and portability. However, traveling gun irrigators are relatively inefficient in terms of water and energy use. The aim of this study was to evaluate innovative telemetry equipment that can be retro-fitted to a travelling gun irrigator to monitor and adjust water application for improved energy and water use efficiency.

Methods

Retro-fitting of telemetry and irrigation technology

Telemetry and irrigation components developed by Seattle Services Pty Ltd. and Tasmanian Institute of Agriculture (TIA) using a microprocessor pressure control system were retro-fitted to a travelling gun irrigator. Components consisted of a solar panel, battery, microprocessor unit, radio and water pressure sensor. Components fitted to the irrigation equipment work in conjunction with a variable speed pump drive (VSD) to maintain water pressure at the nozzle via a real-time feedback loop, regardless of slope or length of the irrigation run. A prototype data logger was fitted to the controller to monitor energy consumption, enabling comparisons between the modified and conventional irrigators.

Trial design, cultural practices and data collection

Trials were conducted during the 2010/2011 season in a commercial carrot crop (*Daucus carota* L., var. Stefano) at the TIA Vegetable Research Facility, (Forth, Tasmania). The soil at the site was a freely draining Ferrosol, typical of those used for carrot production in Tasmania. A commercial carrot crop was grown from 9 November 2010 to 21 March 2011, using normal commercial cultural practices. Trials commenced after establishment of the crop in early December and subsamples to determine yield and quality were hand harvested in March just prior to commercial harvesting.

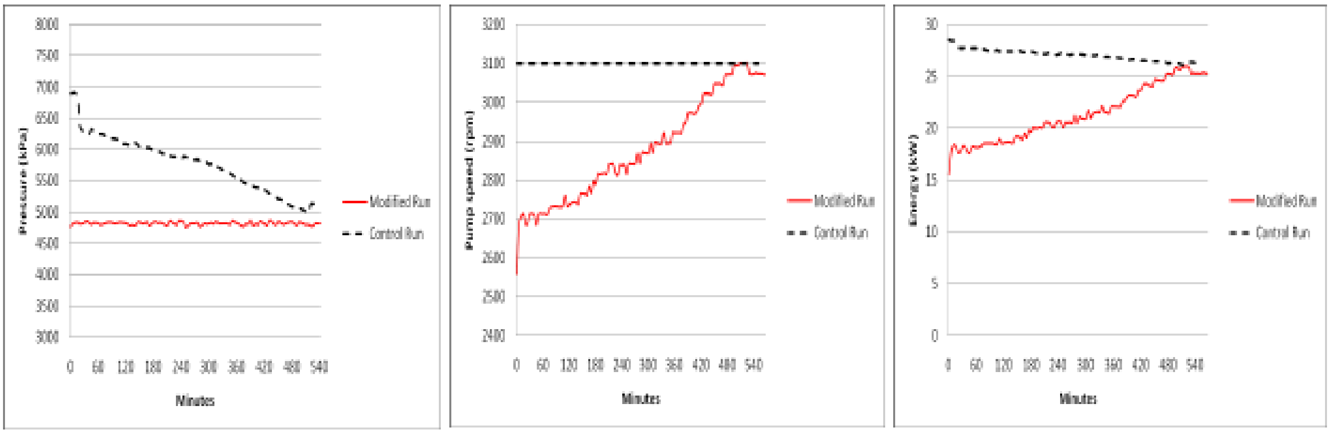
Two irrigation treatments were studied: one using a conventional irritator and one using the modified irrigation run. Each treatment was approximately 350m in length with 12 plots (14m x 20m) plots on either side of the irrigator (total of 24 plots per treatment). Irrigation treatments were reduced due to high seasonal rainfall (513mm, compared to long term average 238mm). A constant target pressure of 414kPa (60 psi) at the gun for the modified treatment was set to equal that at the end furthest from the pump of the un-modified (conventional) irrigated treatment.

Energy consumption was measured and recorded automatically. Water consumption was recorded manually from a water meter before and after irrigation events. Data on emergence and plant population density, yield and quality of carrots, and plant disease assessments were collected to examine the effect of the irrigation treatments on crop performance and disease incidence. Carrots were on the basis of quality into first or second grade, and on the basis of size 'below small' (<25 mm diameter), 'small' (25 to 30 mm), 'medium' (30 to 40 mm) and large >40 mm). Yield was determined from two randomly located linear quadrats (1 m x 1 row) in each plot. Data were analysed by unpaired t-test for equality of means using Genstat Ver. 13 (VSN. International, Hemel Hempstead, UK), statistical software,

Results

Energy and water consumption were 17% and 5% lower respectively in the modified treatment than in the conventional traveller treatment. Figure 1 shows examples of modified and conventional irrigator results for a) pressure (414kPa at gun), b) pump speed (revolutions per minute, rpm) and c) energy consumed (kW) consumed. Rainfall and water consumption during the growing season is shown in Table 1. Irrigation treatments commenced in early December. High rainfall events during the season (513 mm, compared to long term average 238 mm), reduced the number of irrigation events during the season.

Mean yields of 77.4 t/ha and 85.1 t/ha were obtained for conventional and modified travelling gun irrigator, respectively, from similar plant densities (Table 2). Carrot yield was significantly greater (by 7.7 t/ha, 10%) under the modified traveller than the conventional (Table 2). There was a significantly greater weight of large carrots in the modified traveller compared to the conventional, but no significant differences between treatments in yield of other size categories (Table 2). There was significantly greater yield of first grade carrots (small, medium and large) in the modified traveller than the conventional, but no significant difference in second grade (Table 2). No foliage disease was detected during the season.



(a) (b) (c)

Figure 1. Example results for modified and conventional irrigation runs in a commercial carrot crop (2010/2012 season) in Tcasmania, Australia of, a) pressure (kPa at gun, b) pump speed (revolutions per minute, rpm) and c) energy consumed (kW).

Table 1. Rainfall and irrigation applied with modified and conventional travelling gun irrigation treatments in a commercial carrot crop during 210/2011 season.

		Irrigation Applied			
Date	**Total In-crop Rain (mm)**	**Conventional (ML/run area)**	**Conventional (mm)**	**Modified (ML/run area)[a]**	**Modified (mm)**
9-30 Nov 2010	91.8	0.55	3.83	0.55	39.3
1-31 Dec	149.8	0.46	32.9	0.44	31.4

2010					
1-30 Jan 2011	188.2	0.99	70.7	0.89	63.6
1-28 Feb 2011	71.8	1.46	104.3	1.43	102.1
1-21 Mar 2011	11	0.37	26	0.34	25
Totals	**512.6**	**3.83[b]**	**273.2**	**3.65 [b]**	**261.4**

[a] Conventional and modified run area is 1.4 ha (ML/1.4ha).
[b]Values given for ML/1.4ha, equivalent to 2.7ML/ha for the control and 2.6ML/ha for the modified irrigation.

Table 2. Comparison of mean total yield and mean yield of commercial grades of carrots grown under a conventionally operated and modified travelling irrigator.

	Conventional	Modified	t-value (2-tailed)[a]	*P*
Yield of carrots (g/m^2)	7737.5	8510.8	-2.274	<0.05
No. plants/m^2	58.9	59.7	-0.399	ns
Yield of carrots (g/m^2) in size categories:				
Below Small	232.8	241.0	-0.316	ns
Small	822.0	758.1	0.910	ns
Medium	3901.3	4120.2	-1.048	ns
Large	691.4	1020.1	-2.491	<0.05
Total waste	326.0	390.8	-1.495	nsb
Diseased	3.9	4.0	-0.180	ns
Yield of carrots (g/m2) in different quality categories:				
First grade[c]	4433.0	4988.0	-2.69	0.011
Second grade[c]	897.9	756.2	1.36	ns

[a]Data were subjected to unpaired, two-tailed t-test conducted to test equality of means (46df),
[b]ns = not significant.
[c]Total weight of small, medium and large carrots allocated to first or second grade.

Discussion

The reduction in energy use (17%), and water (5%), with improved yield (10%, 7.7 t/ha) under the modified irrigator treatment demonstrates that relatively simple, changes to the irrigation system can bring significant biophysical benefits. Similar results had been achieved using the same equipment with beans earlier in the research (Lambert et al. 2011). Carrot quality was also improved, evident from the significantly higher yield of first grade carrots in the modified traveller treatment, which may be attributable to improved uniformity of water supply over the experimental area. The yield and quality improvements in the modified traveller led to an estimated increase in gross return of $1199/ha over the conventional, based on the premium paid for first grade carrots in the medium and large categories, and extrapolating mean plot yields in different size and quality gradings to a per hectare basis. This study, though compromised by unusually high seasonal rainfall during the carrot crop, supports the need for continued research on machine and delivery system modification for improved energy and water use efficiency in addition to seeking water use efficiency through agronomic adaptations e.g. cultivar selection, plant population, time of planting. The study addresses options for climate change adaption by irrigated agriculture include improving technology and scheduling to enhance on-farm water use efficiency identified in Stokes and Howden (2010), and Jackson (2009). Improved technologies such as the retro-fitted system used in this study can provide innovative solutions to enhance water and energy use efficiency in order to assist climate change adaption and address economic, environmental and social challenges faced by irrigators. Retro-fitted technology developed in this project has the potential to substantially reduce energy consumption for pumping. For instance, if energy prices were to increase by the forecast 15 to 20%, this retro-fitted technology could offset that cost increase and also reduce the amount and so the cost of water. The reductions in energy and water costs would then contribute to amortisation of capital costs involved in implementing the system. A full economic analysis of system performance will be undertaken when the project is completed later in 2012. Nevertheless, the results to date demonstrate a strategy to reduce water and energy consumption during vegetable production. It would be expected that similar findings would occur in other crops and environments.

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