NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Maximising returns from water in the Australian vegetable industry: National report

4. ADOPTION OF IRRIGATION TECHNOLOGY

4.1 ECONOMIC ASSESSMENT OF IRRIGATION TECHNOLOGIES IN THE VEGETABLE INDUSTRY

Although the vegetable industry is considered more efficient than most other agricultural industries in terms of water use efficiency and profitability, stiff competition in the local and international markets has resulted in declining farm profits. Economic sustainability is under serious threat: this is evident from the fact that the number of vegetable farms has declined over time but the farm size has increased. Vegetable farming is very labour-intensive, and labour costs, where major operations such as harvesting are not mechanised, are one of the major components of the total variable costs.

Most vegetable farms have limited water supplies due to reduced general security allocations or shortages due to drought. Therefore, vegetable growers are being encouraged to replace their current, less efficient irrigation systems with more efficient 'high tech' irrigation systems to help improve productivity, profitability, water use efficiency and labour savings.

Installation of systems such as centre pivot or drip involves significant initial capital investment, maintenance and replacement costs. Depending on the crop type, the farmer's management skills, the availability of labour and the pricing and marketing arrangements in place, irrigation systems perform in different ways on different farms in different vegetable crops. It is important to know the type of irrigation technology most suited to a particular vegetable crop and the benefits of switching over to 'high tech' irrigation systems, compared with the costs involved in such systems, before recommendations can be made to farmers. It is also important to consider that, in some states or regions, leasing land is a common practice in the vegetable industry, and, under these circumstances, growers would be reluctant to invest in on-farm infrastructure such as fixed pumps, submains and permanent irrigation systems.

As part of this project, case studies were carried out to analyse the costs and benefits of adopting new irrigation technologies. The crops involved in these economic case studies included sweet corn, processing tomatoes, and lettuce and broccoli. (These case studies are summarised in the appendix to this report, 'An economic assessment of the adoption of improved irrigation technologies in the Australian vegetable industry'.)

The main objectives of the economic analyses were to measure the potential economic and environmental benefits of conversion from an existing, less efficient irrigation system to a new, more efficient irrigation system on several selected case study vegetable farms (different crop types in different vegetable-growing regions in Australia).

More specifically the aims of the economic analysis were:

- to measure potential financial benefits to farmers from different remedial measures;
- to identify the economic and environmental benefits from adopting a more efficient irrigation system; and
- to compare benefits with the costs involved in adopting different improved technologies.

Sophisticated irrigation systems involve significant initial capital investment, and the stream of benefits flow over the life of a system (15 to 20 years). To measure returns from the on-farm investment in such technologies, the benefits from a new system were measured, taking into account the total impacts of the option: improvement in yield, quality, shifts in cropping rotation, reduction in input costs, labour savings, water savings and social and environmental benefits. Similarly, the study considered different costs involved, such as capital cost, installation costs, operational costs, repair and maintenance costs and replacement costs, for a particular farm.

To illustrate the overall benefits of adopting new irrigation technology, a summary of the findings from the sweet corn case study is presented in Tables 20 and 21.

The grower purchased a centre pivot irrigator to replace an existing travelling gun irrigator. The adoption of a more efficient system resulted in a 20% yield increase, from 16 tonnes per hectare under the travelling gun to 19.2 tonnes per hectare using centre pivot irrigation.

Table 20 – Financial benefits of conversion to centre pivot from travelling system, sweet corn, NSW

Measure	Value
Increase in yield (t/ha)	3.2
Price premium on quality ($/t)	$12.50
Water saved (ML/ha)	0.5
Value of water saved ($/ML)	$50.00
Value of electricity saved ($/ha)	$50.00

Table 21 – Economic benefits of conversion to centre pivot irrigation from travelling system, sweet corn, NSW

Measure	Value
Reduction in deep drainage (ML/farm)	15.1
Reduction in loss of water through surface run-off (ML/ha)	0.5
Reduction in losses to infrastructure due to salinity ($/ML)	$15.00
Value of reduction in seepage losses ($/ML)	$43.00

Furthermore, the uniform application of water helped improve the quality of the sweet corn. It was assumed that there would be a $26.00/t premium on 25% of the crop yield, which would be an average of $6.50/t for the 19.2 t/ha crop (pers. comm. M Hickey 2006, based on a 2004/05 season standard market price of $168.00/t). The increase in yield involved an additional harvesting cost of $51.00/ha, therefore the net benefit from yield and quality improvements was $565.00/ha.

The new irrigation system also used 0.5 ML/ha less water to irrigate the sweet corn crop, thus improving water use efficiency by 20%. This not only helped to reduce the cost of production: the saved water was an extra source of income for the farmer.

A positive return on this investment was estimated to occur after the second year of operation.

4.2 IRRIGATION SYSTEM TECHNOLOGY

It is important to identify the best irrigation practice that will allow the vegetable industry to develop into the future. This means using systems that allow efficient use of water, labour and other resources whilst producing a quality product.

There will also be the expectation and opportunity to use unconventional water sources such as reclaimed water. Growers need a full understanding of how much of each 'class' of water can be applied without harmful effects on the crop and soil. Furthermore, the water quality, salinity, suspended solids, ions, trace elements and pathogens may influence the choice of irrigation system. For instance:

- high levels of suspended solids create filtration problems when using drip irrigation;
- sprinkler irrigation methods that wet plant leaves may cause specific ion toxicity problems, e.g. chloride or sodium, at concentrations lower than those that cause problems when using surface and subsurface irrigation methods.

An appropriately designed and operated irrigation system is crucial for maximising production quantity and quality and irrigation efficiency whilst minimising environmental impacts.

There can be no definitive answer as to which type of irrigation system is most suitable for vegetable irrigation, as there are so many variables. The report *Technology and practice for irrigation in vegetables* (Christen et al. 2006), one of a series of reports for this project on maximising returns from water, endeavours to broadly assess the three main irrigation systems, furrow, sprinkler and drip, against the key criteria related to irrigation for vegetables. The main areas of assessment for irrigation systems are against water quality parameters, the likelihood of minimising environmental problems, and the appropriateness for efficient and economic crop production.

Although the method of water application depends on many site-specific and economic considerations, the most efficient system, with the least human and environmental risk, is generally considered to be drip irrigation, and as such the bulk of the *Technology and practice* report focuses on it. Drip irrigation may not always be suitable for a particular agricultural system, however, due to soil physical properties, establishment difficulties, cost considerations and other factors, and these are outlined in the report.

Good irrigation scheduling and management methods are important to maximise production whilst minimising environmental impacts. Good drainage is also required to suit the soil, water and environmental conditions of the irrigation system. All these factors are crucial for the success and sustainability of any irrigated vegetable enterprise.

4.3 IRRIGATION SCHEDULING

Use of advanced irrigation systems does not always translate into high water use efficiency. A 1998 survey of water use efficiency in processing tomato crops by Ashcroft et al. (2001) found that 31% of furrow-irrigated blocks performed as well as or better than 41% of drip-irrigated blocks in terms of tonnes per megalitre. This survey demonstrated that good management of an irrigation system, regardless of the type of system, is the key to achieving high water use efficiency. It should also be added that the same survey showed that the 33 best tomato blocks in the industry, measured in tonnes per megalitre, were drip-irrigated.

Use of irrigation scheduling is a hallmark of good irrigation management. In considering irrigation scheduling currently used in Australian vegetable production, the main technologies are broadly categorised into ‘intuition’; weather-based and water budget systems; simple tools; and electronic irrigation systems. (These categories are adapted from the state report *Maximising returns from water in the Australian vegetable industry: Queensland* by Craig Henderson, 2006, and are detailed below.)

Intuition or gut feel

The intuitive approach usually involves irrigating to a set pattern, intuitively accounting for evaporative demand, rainfall, crop growth stage, and water availability and quality. There is some feedback from monitoring crop performance, and a ‘kick the dirt’ approach to soil moisture assessment. Producers may use this style of irrigation scheduling because:

- Water management is not a high priority for the producer compared with competing issues such as pest control, product marketing, and labour management.
- The producer does not believe an objective measurement system would give better water use efficiency or crop performance, or alternately believes efficiency or production gains would be too small to justify the investment cost and time.
- The producer has previously used irrigation scheduling equipment, and had a bad experience such as equipment failure, poor crop performance, or equipment too complex or costly for the results achieved.
- The producer has previously used irrigation scheduling equipment, and believes that this provided enough knowledge or experience to be able to replicate the results without ongoing investment in objective measures.

Weather-based and water budget systems

Apart from NSW, there is currently very little stand-alone use of water budget approaches in vegetable irrigation, other than relatively simple recording of rainfall and irrigation quantities, and comparing these with intuitive or historical guesstimates of crop water requirements.

In the Murrumbidgee Valley, NSW, evapotranspiration data is readily available through newspaper, phone and fax reports, and is often used in combination with local knowledge or 'gut-feeling' by the grower. In NSW, Waterwatch, an irrigation scheduling service, operates out of the NSW Department of Primary Industries office in Griffith. Waterwatch provides evapotranspiration figures for the previous 14 days, enabling growers to calculate their own crop water needs. The figures are also published in local newspapers. CSIRO Land and Water at Griffith collect and publish the ETo data on their website. Similar Waterwatch services are provided at Dareton and Forbes.

In Tasmania, slightly less than 20% of farmers surveyed by ABS (ABS 2005a) reported using weather-based information to make irrigation decisions. Daily evaporation data is reported in all regional newspapers. It is estimated that well over 50% of the Tasmanian population has household internet access, and growers regularly comment on referring to web-based weather forecasts and rainband maps as part of the irrigation decision process. Although this usage is significant, it is not quantified.

Simple tools, e.g. tensiometers, hand-held manual moisture probes

The use of these relatively simple, non-automated tools occurs in most vegetable crops and growing regions across Australia, but often in concentrated pockets and crop types. An active group of users is usually associated with a specific extension campaign either by government extension officers (e.g. in Carnarvon tomatoes in the mid 1980s, Manjimup potatoes and Bundaberg tomatoes during the early 1990s, and Lockyer lettuce and potatoes during the mid 1990s) or by local resellers with an experienced sales and service person who can provide effective advice on using the tool.

Research has clearly shown that simple equipment such as tensiometers can optimise water use efficiency in most vegetable production systems (Henderson 2003). Originally models with inbuilt pressure gauges demanded fairly significant maintenance to ensure continuously reliable readings, and in recent times became relatively expensive, at $250 per unit. The availability of septum-type systems, with cheap tensiometer tubes ($30) and a loggable electronic reader ($800) capable of repeatable measurement at each tube, has markedly increased the utility of tensiometer-based scheduling systems. Henderson (2003) estimated the full cost of a tensiometer-based scheduling system for crops such as lettuce or brassicas at around $100/ha, including all equipment, labour, and data management requirements.

Electronic irrigation scheduling systems

Electronic scheduling systems cover the full range of capacitance, heat dissipation, and matrix block sensors, with either manual or electronic logging, data storage and distribution. Often these tools have associated software and irrigation management programs. Some systems even fully automate irrigation management by linking to irrigation controllers.

There has been significant interest in these electronic systems, associated with:

- extension and operation by consultancy firms, e.g. Crop Tech P/L in the Bundaberg district, and Serve-Ag in south-eastern Australia. The level of service provided can vary, from supply of the scheduling equipment through to a full irrigation consultancy service, involving the consultant in taking the soil moisture readings, and making ongoing irrigation recommendations.
- extension, sales and technical support by equipment suppliers and retailers – as equipment suppliers see a business opportunity, they promote types and levels of equipment and levels of after-sales service and back-up to interested producers as a commercial service.
- extension and demonstration by government and natural resource management programs such as the Water for Profit program, funded under the Queensland Government Rural Water Use Efficiency initiative (Clark 2003), provide demonstration units and support back-up for a short period, to allow the grower to assess the cost–benefit in ongoing investment in such systems. A project funded by the Murray–Darling Basin Commission from 1998 to 2002 saw moderate levels of adoption of various soil moisture monitoring tools by vegetable growers following campaigns by state agencies in the Murrumbidgee, Murray and Goulburn valleys.

Vegetable processing companies such as Simplot Australia are now progressing into the third season of a program referred to as the Crop Management Service. The program establishes regular crop monitoring and agronomic data collection. Data-logged soil moisture monitoring is a key component of the program. Accurate soil moisture management records are then aligned with yield and quality at processing. Soil moisture management histories are analysed and discussed within grower discussion groups. This program is being conducted in at least 130 sites each season and is potentially an extremely valuable tool to assist with defining irrigation best practice and changes in water use efficiency. The crops currently included in this program are processing potatoes, peas, beans and brassicas.

A general assessment of the use of these electronic systems in Australian vegetable production suggests:

- ongoing use by highly capitalised businesses, with automated irrigation systems and in-house agronomic and electronic specialists to maintain service.
- ongoing use by businesses with a successful relationship with a reliable consultant who is familiar with the integration of these systems in whole farm operations.
- ongoing but lower level use by large scale businesses that purchase some equipment, but not enough to cover their suite and areal extent of normal operations. These businesses often have access to an agronomist (either in-house or external), and use the irrigation scheduling equipment to investigate new production systems, new sites, or any other agronomic change they implement. Once they are confident they have their irrigation relatively well organised, they switch to a calibrated, simpler system (e.g. tensiometer or matrix block), or rely on experience and intuition with the new production strategy. This type of use is more common than the former two practices.

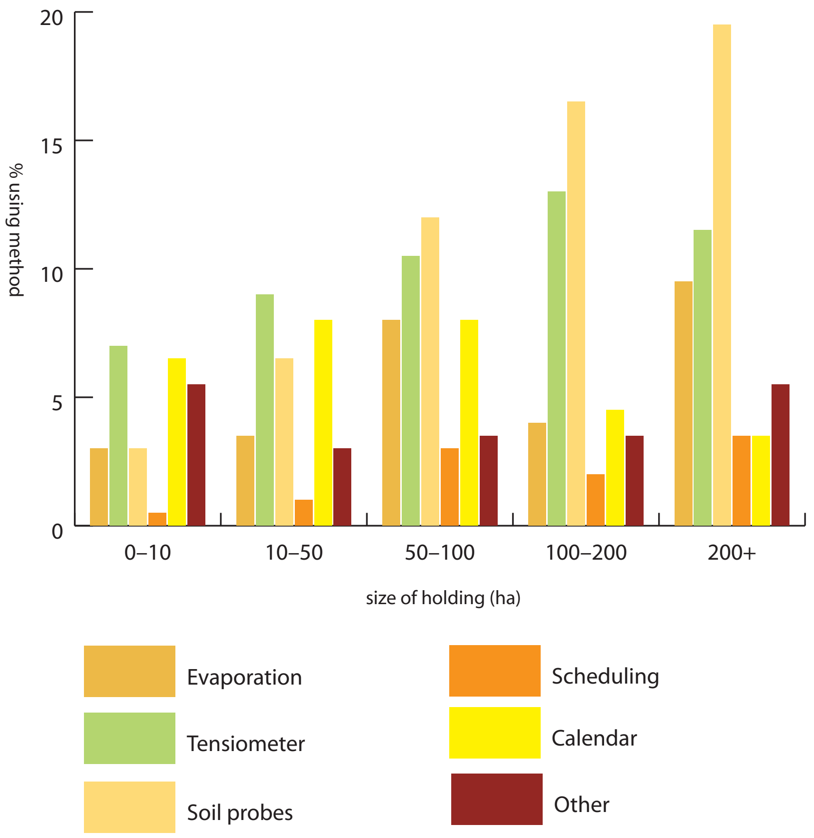
- use of demonstration or leased equipment to evaluate irrigation practices (for example, under the auspices of a Rural Water Use Efficiency type of program), make adjustments and re-evaluate, but without actual investment in private purchase or ongoing lease of the equipment. This is also a relatively common scenario.
- initial use of the electronic systems, but cessation after a short time. Commonly this occurs because of equipment failure (and no redress because of lack of support from the supplier, either because the initial supplier is no longer in business, or the producer is unable to fund ongoing support); or lack of follow-up support by the extension agent (private or public) and consequent producer frustration.

Use of irrigation scheduling systems

Soil moisture monitoring tools are widely used in intensive irrigated vegetable production in Australia. A recent CSIRO draft report (Stirzaker 2005) indicates 21% of Australian farmers use some form of soil moisture monitoring. It is estimated that 16 186 of the 43 774 irrigated establishments surveyed in the ABS water account (ABS 2005a, Table 4.3) have changed and adopted more efficient scheduling.

Figure 8 shows the proportion of vegetable growers using various irrigation scheduling tools.

Figure 8 – Use of irrigation scheduling by vegetable growers in Australia



Source: ABS 2003

The 2000-01 ABS survey (*AgStats*, ABS 2003) indicates that adoption of irrigation scheduling in the vegetable industry lags behind industries such as fruit and nuts, grapes and cotton. There are several explanations for this trend, including the relatively short duration of vegetable crop cycles, the constant rotations used, and the use of sequential plantings of crop, which results in crop of various growth stages on the farm at any one time. Vegetable growers also have a tendency to use tools such as tensiometers for two or three seasons to improve their understanding of the water requirements of a particular block, then discard the tool and use their own judgement.

Use of sophisticated tools such as neutron probes and capacitance probes is more popular on the larger vegetable farms, as indicated in Figure 8, and is often limited to use by irrigation consultants. Lower cost tools such as tensiometers are gaining popularity, and the percentage of vegetable growers using tensiometers would be higher than in most irrigated industries. Use of soil- or weather-based monitoring also varies from region to region.

Whilst tensiometers were previously confined to heavier soil types, recent developments in technology (sand tensiometers) allows tensiometer use even in sandy soils in Western Australia.

Since the 2000/01 survey, the implementation of metered water extraction in some regions, of volumetric water allocations based on crop type, and of industry change towards more manageable, uniform output, low pressure sprinkler and drip systems has given vegetable growers more incentive to better manage irrigation scheduling. As a result, most regions have reported an accelerated adoption of soil moisture monitoring tools among vegetable growers.

5. ACCESS TO IRRIGATION INFORMATION

5.1 NATIONAL IRRIGATION INFORMATION ACCESS

There are several national programs and organisations offering support on irrigation for vegetable growers.

Enviroveg

Originating in Victoria in 2000, the Enviroveg program was commissioned by the Victorian Vegetable Growers Association on behalf of growers in response to community and government beliefs that nutrient loss from horticultural activities was a major contributor to pollution of nearby waterways.

From the website www.ausveg.com.au/enviroveg.cfm

The program was funded by the National Vegetable Levy (AUSVEG) and was first trialled in Victoria before being launched Australia-wide in 2003. It is industry-owned and managed by AUSVEG. The intent is that it should remain industry-owned and that membership of the program should remain free to all levy-paying vegetable growers.

Enviroveg consists of a manual which describes various practices, including irrigation, and a self-assessment checklist against which growers score themselves. It is simply an entry point for growers wishing to implement an environment management system on-farm.

There are 11 elements or sections in the Enviroveg manual. Many cover general industry practices, and others are specific to the growing systems. Elements covered are:

- soil management
- water management
- nutrient management
- pest and disease management
- chemical storage
- hydroponic production
- greenhouse production
- organic production
- air quality
- energy conservation
- waste management
- biodiversity
- biosecurity

Enviroveg produces a newsletter, and identifies subsidies, grants or funding available to growers wishing to make environmental improvements on their farm. Growers can eventually achieve certification through Enviroveg Environmental Assurance. The program may also give growers a marketing edge.

CRC Irrigation Futures

In 2003, the Cooperative Research Centre for Irrigation Futures was formed as an entity to encourage a national approach to irrigation research, education and training. Through its member institutions, it provides a range of formal tertiary education courses, industry workshops and forums, research programs and training packages, many of which are appropriate for vegetable producers.

CRC Irrigation Futures website www.irrigationfutures.org.au

Irrigation Association of Australia

Apart from training and networking opportunities for irrigation industry service professionals, one of the main contributions of the IAA is its annual national conference. The IAA conference showcases the latest developments in irrigation technology and practice, provides forums for vegetable producers and industry professionals to interact, and showcases the latest equipment from irrigation industry suppliers. Many large vegetable producers have attended these conferences in the past, or alternatively funded participation by their key irrigation staff.

IAA website www.irrigation.org.au

The IAA also produces a range of irrigation publications, particularly associated with equipment performance and evaluation, maintenance and improvement.

The HAL Water Initiative

Horticulture Australia Ltd established the HAL Water Initiative in 2003. It assists horticulture by articulating the economic and social benefits of horticultural water use. It also demonstrates the environmental credentials of horticulture and invests in projects that further enhance the sustainability and reputation of the industry.

HAL Water Initiative website www.rmcg.com.au

In the short term, the HAL Water Initiative responds to grower needs on resource issues, drought response, submissions to water property rights studies and communications to governments and water authorities.

In the long term, it encourages new technology and better practices for water management, assessing the water quality impacts and requirements for major crops, and developing and enhancing best management practices for controlling salinity, nutrients, sediments and biocides on horticultural properties.

5.2 IRRIGATION INFORMATION PROGRAMS

Queensland: Rural Water Use Efficiency Initiative

Queensland vegetable industries have participated in the Queensland Government Rural Water Use Efficiency improvement programs that commenced in 1999 and have continued in various guises until the present day. The program targeted provision of information and irrigation improvement services, with on-ground field staff employed under the Water for Profit banner, a section of Growcom P/L (formerly Queensland Fruit and Vegetable Growers).

The program includes a broad range of extension services, including one-on-one advice to producers, organised field days and training courses, a dedicated website, and a

resource CD that includes a wide range of generated and sourced horticultural irrigation information. There are also awareness and technical articles in industry journals, such as *Fruit and Vegetable News* and *Good Fruit and Vegetables*.

The best summary of this service was the RWUE's 2003 milestone report (Clark 2003). It concludes that, by 2003, 90% of horticultural growers were aware of the extension service, with 45% of horticulture growers implementing system improvements or changing irrigation practices.

Rural Water Use Efficiency website: www.nrm.qld.gov.au/rwue/

A separate review of the RWUE program (Coutts and Bell 2003) stated that 70% of horticultural industry respondents reported participation in the RWUE initiative, with 53% rating the knowledge gained as moderate or better. About 70% of horticultural growers indicated they had or would make changes to their irrigation practices as a result of involvement with the program, whilst the numbers suggest that around 41% of Queensland horticultural irrigators were successful applicants to the RWUE Financial Incentive Scheme. The RWUE reviewers found 'This combination of awareness and participation is an incredible achievement in any circumstances'. This review provided a comprehensive analysis of the benefits to vegetable industries and the wider community from the RWUE training and extension program.

Queensland: Department of Primary Industries and Fisheries

The Queensland Department of Primary Industries and Fisheries (DPI&F) provides several resources of irrigation information to vegetable producers. These include, but are not limited to:

- Agrilink and Crop Management handbooks: these have a detailed section on irrigation management included in the total package of farming information. Vegetable crops covered in detail include lettuce, rockmelon/honeydew, sweetpotato, tomato, and brassicas; onion, potato, capsicum and chilli Agrilink handbooks have been published but out of print)
- DPI&F Notes (from the Department of Primary Industries and Fisheries website).

Fact sheets:

http://www.nrm.qld.gov.au/rwue/factsheets.html

http://www.growcom.com.au/WaterForProfit_fs.html

DPI&F website www.dpi.qld.gov.au

Agrilink home http://www2.dpi.qld.gov.au/agrilink

Queensland consultancy services

The large vegetable-growing areas are serviced by private consultancies; certainly there are significant consultant services targeting vegetable production on the Atherton Tableland, Bowen, Burnett, South Coast, Lockyer, Eastern Darling Downs and Granite Belt. These consultants span individuals with a few key clients through to regional businesses and some businesses with formal links to national alliances with significant Australia-wide presence. The consultants offer advisory and research services ranging from one-off inquiries to irrigation system and infrastructure evaluation, through to regular and intense irrigation monitoring and management. In recent years, many of these consultants have not been as active in irrigation management as in the past: this may be because, as growers become larger, they may often employ their own irrigation managers, with access to much of the automated logging and controller equipment that was previously the bailiwick of the consultancy firms.

Queensland agribusiness

Most of the Queensland vegetable-growing regions have several irrigation equipment and service supply companies. Apart from advice on equipment selection, maintenance and operation, many of them also provide general advice on issues such as using tensiometers for irrigation scheduling. These well-established companies are an important traditional source of general information to vegetable producers in the major vegetable-growing regions.

In recent years, many wholesale equipment suppliers, particularly the drip equipment manufacturers, have had their own network of technical and sales staff that interact directly with vegetable producers. This extends not just to equipment advice but to actual demonstration trials, field days, and extension materials. In addition, several companies offer intensive individual support to larger growers using their products for the first time. This intensive, one-to-one service has been an important factor where there has been large scale changes in irrigation systems (e.g. conversion of sprinkler systems to drip in the Lockyer and Granite Belt regions in the past few years).

Queensland irrigation training and incentive programs for irrigators

A major training and extension program for production horticultural growers (including vegetable producers) since 1999 has been the Rural Water Use Efficiency program. Since 2004, Stage 2 of the adoption/training program is being delivered by Growcom P/L under the Water for Profit badge.

From the Executive Summary of the Final Milestone Report

During Stage 1 of the Horticulture RWUE initiative, the Water for Profit program was led by Queensland Fruit and Vegetable Growers (now Growcom P/L), and involved staff from DPI&F and the National Centre for Engineering in Agriculture. Stage 1 has been reviewed and extensively reported on (Clark 2003). As at June 2003, during the four-year program, Water for Profit:

- has a high level of recognition in the horticultural industries with over 90% of growers aware of the program and the drive to increase irrigation efficiency;
- has had almost 45% of horticultural growers participating in changed irrigation management practice and improvements;
- has had over 6000 attendances at activities and workshops aimed at assisting growers improve irrigation efficiency;
- has had almost 1500 individual growers participate in BMP activities;
- has assisted over 1400 growers through the Rural Water Use Efficiency Financial Incentive Scheme;
- has generated more than $162 million of gains in water savings and productivity;
- significantly, has returned $23 in efficiency gains for every $1 invested in the program by the state government;
- was announced as the winner of the FarmBis Training and Education category of the Queensland Primary Industries Week Awards in April 2003;
- has produced over eighty information sheets to help growers improve irrigation efficiency.

The program delivered training through visits to individual farm sites, industry workshops and field days, information sheets on the web, a stand-alone CD of fact sheets (Water for Profit 2005), written media, including *Fruit and vegetable news*, local, regional and state newspapers, Irrigation Association of Australia National Conferences, radio and television awareness appearances.

The program also encouraged participation through a financial incentives scheme to assist producers participate in system infrastructure improvement, adopting irrigation scheduling methods, or individual consultancy or training. Across Queensland horticultural producers, there were 2073 applications for incentive packages, with approvals consisting of

29 for training, 799 for system improvement, 607 for irrigation scheduling equipment and application, and 59 for water meters (total approvals 1494).

Stage 2 of the Water for Profit industry training program is continuing at a reduced level of investment and activity. It is still providing training workshops for issues such as salinity and nutrient management, and on-farm assistance with system evaluation and improvement, and implementation of irrigation scheduling (pers. comm. Wallace).

Apart from the Water for Profit program, other groups and organisations are delivering training and extension programs with vegetable growers in Queensland regions. Individual industries have irrigation components as part of their overall productivity and sustainability extension programs. For example, DPI&F is working with sweetpotato growers to improve irrigation at establishment, a critical determinant of root yield and quality (pers. comm. Eric Coleman). Australian Horticultural Research is working with lettuce growers in the Lockyer Valley to improve irrigation scheduling using soil moisture monitoring equipment.

NSW: WaterWise on the Farm

Since 1995, WaterWise on-farm training has been carried out by NSW Department of Primary Industries across all major vegetable production regions in NSW. WaterWise training has been a prerequisite for eligibility to primary producers for grants and loans for on-farm irrigation layout improvements and investment in 'high tech', efficient irrigation and monitoring. The $25 million Irrigated Agriculture Water Use Efficiency Incentive Scheme was administered by the NSW Rural Assistance Authority.

A review of the WaterWise training program in 2003 showed that over 4000 people attended workshops, and over 80% of participants surveyed said they had much improved knowledge of soil, plant water use and system efficiency, monitoring soil water, scheduling and how to develop a farm irrigation plan. Ninety per cent believed they had improved skills to assess soil, measure irrigation system output, and develop irrigation schedules. This program is ongoing.

Non-government irrigation training programs are also carried out by irrigation companies in the Land and Water Management Plan areas, including Murrumbidgee Irrigation, Coleambally Irrigation, Murray Irrigation, Western Murray Irrigation and Jemalong Irrigation near Forbes, which also provide irrigation system improvement incentives.

NSW: Catchment Blueprint Irrigation Training

Under the NSW River Catchment Blueprints for the major irrigation valleys in NSW, water and environmental management training is provided by private water companies. Under the Land and Water Management Plans (LWMP) for irrigation districts in NSW, there are programs such as Envirowise, which operates in the MIA, and is run by Murrumbidgee Irrigation, providing training and incentives for uptake in whole farm planning, drainage recycling, and 'high tech' horticulture systems. Similar programs are offered in other major vegetable regions, such as Coleambally Irrigation and Murray Irrigation.

FarmWise is the education program which incorporates the objectives and principles of MIA EnviroWise into a locally focused education program. Farm Wise is a prerequisite for gaining MIA Envirowise funding. The course includes an introduction to MIA EnviroWise, goal setting and team skills, financial management, irrigation management skills, whole farm planning and vegetation management. MIA EnviroWise also runs a water efficiency project, 'More Crop per Drop', which has proven to be a powerful tool in assessing the water use efficiency of various cropping systems. The concepts of water budgeting and benchmarking are an important part of the FarmWise program. Course participants are also trained to use Waterwatch figures to finetune water budgets and monitor water use.

NSW: Government incentives for irrigation system upgrades (previously available in non-LWMP areas)

Until 2005, farmers completing recognised training such as WaterWise on the Farm Introduction to Irrigation Management workshops were eligible to apply for up to:

- $2000 to improve crop water use monitoring (50% of the cost of equipment or services)
- $12 000 for 50% of the cost of an irrigation and drainage management plan (IDMP)
- $15 000 for 50% of the cost of works or equipment recommended in the IDMP to improve water use efficiency.

Within irrigation company boundaries, a similar and more attractive incentives program is available, which is partly government-funded.

All of these programs incorporate a training package.

Other schemes available to vegetable growers include the Special Conservation Scheme – Irrigation, a low interest loan of up to $100 000 for irrigation system upgrades which benefit the farmer, the community and the environment. It is administered by the Rural Assistance Authority (RAA).

Victoria: irrigation information programs

Less than 30% of Victorian vegetable growers appear to have participated in formal irrigation training, although where irrigation management is more critical in crop performance, as in the north of Victoria or where more sophisticated systems are used, training rates are higher. Growers look to government agencies (DPI Victoria and water providers), irrigation equipment suppliers, consultants and other farmers for advice on their irrigation practices.

Tasmania: irrigation information programs

Three programs have focused upon irrigation efficiency monitoring within the Tasmanian vegetable industry in recent seasons:

- A Waterwise Irrigation training program was delivered to over 200 participants in 2001. The training was delivered as five half-day training sessions at 14 locations and funded under the Natural Heritage Trust.
- The potato and vegetable processing industry crop management service has encouraged soil moisture monitoring and group review of irrigation efficiency within processing potato, bean, pea and broccoli crops contracted to Simplot Australia. Irrigation scheduling based upon soil moisture monitoring has been established within approximately 130 sites each season, commencing in 2003.
- The DPIWE Water Use Efficiency project has worked within potato, vegetable and dairy discussion groups to raise grower awareness of irrigation management opportunities and the current variation in water use efficiency occurring within each industry.

South Australia: irrigation information programs

1. The Greenhouse Modernisation project at Virginia Horticulture Centre (VHC) on the Northern Adelaide Plains was established to demonstrate and promote technologies

and best practices which can benefit growers in the region (mainly greenhouse tomatoes, capsicum and cucumber). It is an experimental centre which demonstrates success or failures in systems, techniques or production methods, including irrigation, under 'high tech' greenhouse conditions.

2. The Horticulture Salinity project is conducting research to manage horticultural production under a more saline environment (including research on techniques for reducing the effects of saline water on sprinkler-irrigated vegetables such as onions and potatoes). This project is funded by the Centre for Natural Resource Management (CNRM) and delivered by the South Australian Research and Development Institute (SARDI, PIRSA).
3. The Irrigation Management in Processing Potatoes in the South-East project suite supports the adoption of soil moisture monitoring devices to meet targets of yield and quality, in addition to the development and use of irrigation management tools and checklist.

Western Australia: WaterWise on the Farm workshops, Department of Agriculture and Food

The WWOTF Program was established by the Department of Agriculture and Food as a pilot in 2002. Its aims initially were to develop a suitable irrigation training program to increase water use efficiency by irrigators, and to determine the level of interest amongst irrigators in WA.

The Program expands on the training model and information originally developed and used in New South Wales. The training material from NSW Waterwise on the Farm is customised for Western Australia and the specific industries that are targeted.

The training is delivered to small groups of farmers to enhance the adult learning process. Each group has 4 formal workshops on specific irrigation management topics, including assessing farm soil and water resources, evaluating the efficiency of the existing irrigation system, scheduling irrigation and benchmarking against others' performance, and preparing an Irrigation and Drainage Plan. The addition of one-on-one training in 2004/05 as a follow-up to the workshops has increased the cost of the course per participant, but feedback from the participants has shown that it is one of the key features that contribute to changes in irrigation systems. Rebates were available to irrigators in 2004/05 to upgrade irrigation systems, based on an approved irrigation plan, up to $2000 per irrigation plan.

Funding for the WWOTF program over the last 2 years has been provided by the Department of Agriculture and Food, Department of Premier and Cabinet through the State Water Strategy office, the National Landcare Program, Farmbis and farmer contributions.

Achievements of the Pilot Program for WaterWise on the Farm

- Development of training material for Western Australia – editing and enhancing the NSW training material.
- Delivery of 19 training courses (76 workshops) over 4 years, with an extra training course being organised to run later in this year. So far 175 farmers have been trained.
- Three Department of Agriculture and Food Staff trained in the delivery of WaterWise on the Farm for Western Australian conditions.
- Two irrigation consultants have been trained in delivery of specific WWOTF workshop components.

- Between 30 and 35 irrigators will access the grant rebate to upgrade their irrigation systems this year.
- A formal independent evaluation of the WWOTF Program was carried out in 2004. It showed the training program was effective in delivering irrigation training resulting in change in irrigation practice, and identified areas where the delivery could be improved.
- Development of an AGMAPS land resource and management information CD for Wanneroo irrigators.
- Upgrading a Seasonal Water Use computer program (Irricalc) for use in Western Australia.
- Production of a quarterly WaterWise on the Farm newsletter.
- Liaison between the Department of Agriculture and Food and the Department of Environment on irrigation management training of farmers and improving water use efficiency, raising awareness of what WWOTF training can achieve.
- Formation of an Industry Steering Committee to ensure the training stays relevant to each of the irrigation industries.
- The WWOTF Program has attracted funding from the Natural Heritage Trust (NHT) and National Landcare Program (NLP) during 2004/2005 and 2005/2006.

What has been learnt from the Pilot WWOTF Program?

- The preferred learning style of farmers and irrigators in the WWOTF Program is through practical on-farm sessions.
- Irrigation management should use objectively gathered data to schedule the irrigation applications. There is a need for a decision support program to take out all the number-crunching for farmers.
- Irrigators undertaking the training have seen value in the Program to their business and many have made changes to their irrigation systems. Many irrigators started the Program believing they did not need to make changes to their systems. Future evaluations will include the number of changes made and the amount of water estimated as saved.
- There is little incentive for irrigators to improve their water use efficiency when there is no regulatory requirement to monitor and report water use. Improved water policy is needed to reinforce the need for irrigators to make changes. This will also encourage increased participation in WWOTF.
- To date there has been no effective monitoring of water use, making it difficult for individual farmers and growers to benchmark their irrigation.

Recommendations for 2005–06

Funding has been sourced from NHT and NLP for 2005–06 to continue the WWOTF Program in the South-West region ($378 000). This includes $248 000 for training and establishing irrigation demonstration sites, and $130 000 for irrigator rebates to upgrade irrigation systems.

Seven groups are being planned as the target for irrigation training for 2005-06, from irrigators in the citrus, pome fruit, vegetables and dairy industries.

1. The WWOTF Program is supported to continue for 2005–06, with 7 irrigation farmer groups plus 4 demonstration sites for best management practice in irrigation and nutrient management.
2. State agency funding of $140 000 is required as matching contribution to the NLP funding available for this work.

5.3 IRRIGATION POLICY INITIATIVES

Victoria: Stressed Rivers Program

The Stressed Rivers Program aims to restore aspects of the flow regime of the greatest benefit to habitats and to undertake other work to improve habitats. At present only 35 river reaches have been identified as stressed under the program, rather fewer than the 65 per cent that are considered to be in poor condition.

The Snowy River is conspicuous by its absence from the program, although the Snowy River Inquiry indicated that much of the river could certainly be described as stressed. Intergovernmental agreement has been required to address the problems of the Snowy River. The Goulburn River is also not included, even though it is one of the most stressed rivers in the state. The Goulburn was excluded because its main physical feature, the Big Eildon Dam, cannot be removed. Practicability of relieving stress in rivers was one of the criteria for choosing rivers for the program.

Improving the condition of stressed rivers appears to be feasible, and is likely to produce benefits beyond the river itself, but reversing the impacts of past mistakes on these rivers will involve considerable commitment and resources.

River flows are vital to restoration of stressed rivers. Provisions for these can be included in Streamflow Management Plans. These are currently being co-ordinated with the Stressed Rivers Program through the River Health Program.

Victoria: The Farm Dams (Irrigation) Review

Recent studies have shown that dams can reduce the annual run-off from the catchment by twice the volume of the holding capacity of the dams. The cumulative effect of large private dams or thousands of small dams can be substantial.

It was found that farmers in the upper river catchments felt aggrieved that their traditional 'right' to build dams was under threat while irrigators lower in the catchment were concerned that the proliferation of dams in the upper catchment would deplete their supplies. The Government confirmed the following principles:

1. The total water resources of a catchment should be included within the water allocation regime.
2. Water resource management issues involve the total catchment and require a partnership between the community and government.
3. Allocation mechanisms should be simple, efficient and equitable.
4. As the value of water to the community increases, so should the management effort to allocate and protect the water resources.
5. All water users should share in the cost of managing the water resources of a catchment.

In addition, the Government added that: 'A sound, well-regulated system [for water allocation and management] is needed that provides security for existing users and opportunity for future development. Further development of water trading will enable water to move equitably to enterprises that provide the best economic return.'

Victoria: Improving irrigation infrastructure

Irrigation infrastructure must be both efficient and reliable to provide a secure supply for water users and to minimise any unnecessary wastage of such a precious resource. This infrastructure must also be well maintained to ensure that current safety standards are maintained.

As irrigation infrastructure such as dams, weirs and channels age, this infrastructure must be upgraded to:

- continue operating effectively and reliably
- address the outcomes of recent technical assessments
- comply with current safety and design standards.

The Victorian Government is working with rural water authorities to improve irrigation infrastructure or to consider phasing out parts of the irrigation distribution system where they are becoming nonviable. Some examples of infrastructure upgrade projects are given below.

Sunraysia Irrigation Project: The Sunraysia region, near Mildura, encompasses the Merbein, Red Cliffs and Robinvale pumped irrigation districts of Lower Murray Urban and Rural Water together with the pumped irrigation district of the First Mildura Irrigation Trust. Much of the irrigation infrastructure currently in use in the Sunraysia region was constructed between 50 and 100 years ago.

The Sunraysia Irrigation Project aims to improve the effectiveness of existing irrigation systems in the Sunraysia region. The Victorian Government has made an initial funding commitment of $20 million from the Victorian Water Trust over 4 years for the upgrade or replacement of aging infrastructure in the region.

Eildon Dam Improvement Project: The Eildon Dam Improvement Project is one of the most significant irrigation infrastructure upgrades currently under way in Victoria. Lake Eildon, constructed in the 1950s, provides around 60% of the water used in the Goulburn–Murray Irrigation District. The Victorian Government has contributed $11 million to the project to date, and will provide a further financial contribution as part of the Sales Water Reform Package. The $52.5 million project will secure the future of Lake Eildon for the Victorian community by:

- increasing the spillway capacity
- ensuring the dam meets current design standards
- protecting the dam against severe earthquakes.

Irrigation infrastructure efficiency: Many structures in the irrigation headworks and distribution systems were built several decades ago, before the development of current water-efficient technologies. By improving the efficiency of some existing infrastructure, water can be recovered for the environment or for new development, and there is the potential to improve the level of service to water users.

Opportunities to improve irrigation infrastructure efficiency include:

- replacing open channels, which have high seepage and evaporation losses, with more efficient closed pipelines;
- altering the size or shape of water storages to reduce surface are and thereby reduce losses to evaporation;

- installing meters or automated regulators on channel/pipe outlets so that water deliveries can be more accurately measured and more efficiently operated.

South Australia: vegetable production projects

There are a number of South Australian programs relating directly to vegetable production.

1. The Sustainable Horticultural Development project is part of the continuing Northern Adelaide Plains (NAP) Landcare Project, with PIRSA, VHC and Rural Solutions SA in 2005–06 assisting with sustainable horticulture development to optimise use of water resources on the Northern Adelaide Plains and minimise drainage problems. The project involves working with industry to identify key issues and ensure that activities and goals are consistent with industry needs. Demonstration sites are used to develop specifications for best irrigation practices that maximise productivity and minimise drainage and salinity issues. The sites will also be used on the NAP and in other areas to encourage adoption of improved irrigation practices. Extension material will be developed and the project will provide input into the strategic planning and drainage components of the wider VHC Landcare program.
2. The Virginia Flood Response project was set up in response to major flooding in November 2005 on the Northern Adelaide Plains. Damage to crops (mainly vegetables), machinery and buildings was estimated at least $40 million. One-third of the state's greenhouse industry had been affected. Growers identified financial counselling, technical advice and financial support as immediate priorities. More than $4 million in assistance was promised to combat the Virginia floods, including $3.5 million to fund $10 000 grants for up to 350 affected growers, $500 000 to help local councils for clean-up operations, and $250 000 towards emptying septic tanks and pumping pooled surface water from properties. A Recovery Centre was also set up at VHC.

Other South Australian state programs relate indirectly to vegetable production and include a range of projects largely coordinated through the newly formed Natural Resource Management areas across the state, PIRSA and the Department of Water, Land and Biodiversity Conservation (DWLBC). The projects relate to a range of issues for sustainable water management including:

- maintenance and rehabilitation of irrigation infrastructure (e.g. bores, channels, pressurisation of schemes)
- water allocations and monitoring (e.g. conversion from area-based to volumetric, meter installation, scheduling, testwells)
- resource management (e.g. GIS information centres for new developments in the South East and the Riverland)
- flood and drought response (e.g. after flooding at Virginia and reduced allocations due to drought along the River Murray).

Western Australia: State Water Strategy

Drivers for change in irrigated agriculture have included:

- policy reforms: monitoring, title security, and regulated markets that help reveal the real value of water, and capital support to upgrade old systems to allow more efficient application

- state-wide review of land suitability for irrigation development. Unlike much of the eastern states, Western Australia still has scope to develop. Pressure on water supplies in the south will shift development north.
- water use data for planning purposes (distribution, economic value in different regions, future demands of water)
- farm and rural water supplies: ongoing research and advice for better water supply management, and tools to assist farmers to evaluate and design on-farm water supplies
- commitment to 20 per cent water recycling in Perth region by 2012
- Water Reuse Steering Committee with representatives from government agencies and CSIRO, and a recycling strategy
- broad market assessment of opportunities for water recycling on the Swan coastal plain
- grey water reuse
- strategic alliances with CSIRO and Department of Health.

Ambitious and vital long-term targets have been outlined in the State Water Strategy:

- adequate water resources within a sustainable framework
- a 14% reduction in consumption per person per year (that is, 155 kL) by 2012
- 20% recycling of wastewater by 2012
- a review of irrigation water use in Western Australia.

As a result of the Final Report of the Irrigation Review (Western Australian Irrigation Review Steering Committee 2005), wide-ranging reforms to water allocation and monitoring, licensing charges, water property rights, water trading, and integration of land use and water planning are now being implemented.

6. RESEARCH, DEVELOPMENT AND EXTENSION PRIORITIES

6.1 QUEENSLAND: R, D & E PRIORITIES

In Queensland, apart from the Water for Profit program, other groups and organisations are delivering training and extension programs with vegetable growers in Queensland regions. Individual industries have irrigation components as part of their overall productivity and sustainability extension programs. For example, DPI&F is working with sweetpotato growers to improve irrigation at establishment, a critical determinant of root yield and quality (pers. comm. Eric Coleman). Australian Horticultural Research is working with lettuce growers in the Lockyer Valley to improve irrigation scheduling using soil moisture monitoring equipment.

6.2 NSW: R, D & E PRIORITIES

In NSW, there are multiple players in research, development and extension, both as funders and providers. These players include the irrigation corporations, universities, CSIRO and NSW DPI, and relevant CRCs and research and development corporations. Extension is primarily provided by NSW DPI District Horticulturists and Irrigation Officers who operate in all the major irrigation catchments, providing advice and training to clients. WaterWise on the Farm courses are held regularly, with horticultural producers amongst the major clients. The field vegetable team at Yanco have an ongoing program of promoting conversion to more efficient irrigation systems and to the use of soil moisture monitoring in vegetable crops in the MIA.

Water Smart farms in the Sydney Basin

(Proposed.) *Partners* — University of Western Sydney in collaboration with NSW DPI and funded through the Department of Energy, Utilities and Sustainability Water Savings Fund.

Objectives — Reduce the use of water for irrigation from the Sydney potable water supply, and increase water available in-stream for environmental uses in the Sydney Basin.

The main target group is irrigators in the Sydney Basin using either potable supplies (from Sydney Water) or surface supplies of water for irrigation. The main activities will include:

- Extend the WaterWise on the Farm initiative to additional sectors of the irrigation industry in the Sydney Basin that have had low involvement because, primarily, of culturally and linguistically diverse background (CLDB) community issues.
- Demonstrate innovative approaches to working closely with CLDB irrigator groups to achieve environmental outcomes.
- Provide education and training advice and financial incentives to retrofit efficient sprinkler heads on current inefficient sprinkler irrigation systems or technology upgrades (targeted both at irrigators who extract water directly from streams, and at users of potable water supplies).
- Provide education and training advice and financial incentives to install water harvesting and reuse systems where the potable water supply is currently being used for irrigation.

Optimisation of water and nutrient balance inputs for greenhouse and hydroponics vegetable production

Partners — NSW DPI Gosford and University of Western Sydney with funding from the CRC for Irrigation Futures.

Objective — To optimise water and nutrient use efficiency in low to medium technology greenhouses through improved understanding of current water and nutrient management and introduction of better practices, such as water recycling, and better decision making.

Activities — To date, 15 greenhouse growers in the Sydney Basin have participated in a survey looking at current water and nutrient management practices. Three sites for intensive investigation have been selected, and a series of carefully controlled experiments have been designed to obtain technical information on different properties of substrates, crop water use and greenhouse environmental parameters. This information will be turned into knowledge to help growers to properly manage or finetune irrigation for greenhouse-grown vegetables. Water balances from each of the 3 sites will be determined.

The main output from the investigations will be a decision support system or model to help provide estimates of crop water use requirements and optimal irrigation scheduling under a range of different environmental conditions for successful production of crops such as tomatoes and cucumbers.

6.3 VICTORIA: R, D & E PRIORITIES

Vegetable Growers Association
www.vga.org.au

The Victorian vegetable industry coordinates the development and delivery of local research and development (R&D) activities through the Vegetable Growers' Association, which has commodity-based representatives on national committees under AUSVEG. Funding for research is provided through the industry (AUSVEG) and federal (Horticulture Australia Ltd) and state (DPI) governments. Meetings between industry members and other stakeholders are convened annually to review progress and priorities for R&D. Recommendations are then relayed to influence the national program.

State government priorities are also reviewed regularly, and funding allocated through a set of Key Projects within an Agricultural Development program. The importance of water management is currently reflected in projects focussing on productivity in plant industries and the ecosystem impacts of agriculture. Current priorities for action within a 3-year (2005–08) funding strategy for horticulture include:

- Improve the efficient use of irrigation water and nutrients by developing new technologies to match applications to crop requirements.
- Increase the use of waste water to produce crops without adversely affecting the safety of produce or soil health.
- Develop production and post-harvest technologies to improve product quality and minimise environmental impacts.
- Facilitate accelerated adoption of improved technologies and best practices and industry preparedness and response to emergencies, including biosecurity threats.

6.4 TASMANIA: R, D & E PRIORITIES

Research, development and extension priorities in Tasmania are reviewed annually by the Agricultural Research and Advisory Committee (ARAC).

With recent losses of market share to imported products it has become increasingly clear that the industry needs to achieve high levels of productivity and minimise input costs to be cost-competitive in a world market. Two areas of underpinning research and extension identified are:

- Irrigation efficiency training and demonstration, particularly skill training to manage 'new' types of irrigation systems, scheduling tools and crop/soil management on a wider range of soil types than traditionally irrigated in Tasmania.
- Clear economic drivers to support improved irrigation management, published benchmarks of economic return per megalitre relevant to the main vegetable crops, and clear demonstration of potential to improve return per megalitre applied.

6.5 SOUTH AUSTRALIA: R, D & E PRIORITIES

The issues and research and extension priorities for the South Australian irrigated vegetable industry (Table 22) were identified after consultation with various government and industry personnel working in the field. Some of the priorities apply across regions and to other crops as well as vegetables.

Table 22 – South Australia research and development priorities

Issues	Research and extension priorities
Lack of irrigation benchmarks	Facilitate irrigation benchmarking studies with vegetable focus groups to identify potential optimum performance parameters for that region and further research, extension and training needs within those groups. Successful studies have been conducted with growers of potatoes and fruit crops in South Australia, providing incentives for improvement.
Soil and groundwater toxic build-up or contamination	Develop best management practices for linked inputs applied to vegetables such as water and fertilisers to prevent toxic build-up or drainage of salinity and nutrients. Improved understanding of full soil chemical analysis and subsequent timely recommendations to improve drainage and nutrient retention e.g. addition of gypsum, organic matter or deep ripping. Management of these issues is also important for environmental management planning.
Reduced water allocations during drought	Developing best management practices to manage vegetable crops and rotations under reduced water allocations on crop yield and quality. More information is needed to understand impacts and options from using less water e.g. plant less, forego yield and/or quality.
Rising watertables	Promote and support irrigation training, particularly for non-English speaking vegetable growers. Concentrated glasshouse production areas on the Northern Adelaide Plains suffer from high watertables, despite modern irrigation and pumping systems. There is a need to develop a culture of irrigation scheduling, recording and monitoring water and fertiliser inputs to manage on-farm and regional watertables.
Decline of soil structure under precision irrigation	Identify negative impacts of precision irrigation systems such as centre pivots or drip irrigation on soil structure. In dryland areas, precision irrigation systems have been introduced for vegetables, and, despite best management practice, have led to a change in soil structure and chemistry, increased silt loads (affecting drip irrigation), and increased sodicity (particularly of subsoil and groundwater).

7. TRENDS IN THE VEGETABLE INDUSTRY

The drought years of 2001 to 2005 highlighted the value of water to the Australian vegetable industry. In many valleys throughout south-eastern Australia, high-priced temporary water transfers were made to vegetable crops, and, in most situations, production levels were maintained. In some valleys, water was trading up to 400% above its normal value. Although the purchase of temporary water increased production costs, profitability remained fair for most vegetable crops, and contracts for processed vegetables were met.

Despite this apparent buoyancy in the vegetable industry, this same period saw relatively few new growers enter the industry, and, in most cases, vegetable production levels either remained stable, or declined. Rather than water, it was market forces which were largely responsible for this change during the 2000 to 2005 period. For example, it was during this period that the export carrot and cauliflower industries in Western Australia experienced strong competition from overseas competitors in South-East Asian markets. Apart from regional periodic water shortages (for example, Werribee in 2003/04), water scarcity had little to do with the decline. Some industry analysts differ in their view of the future and the effects water will have on it. At the AUSVEG summit in June 2005, Dr David McKinna presented his view of the future for the vegetable industry, that 'the cost and availability of water will become an increasing constraint to future developments, and that water-intensive crops and low value crops will become increasingly uncompetitive.'

A trend towards larger farm operations, the increasing role of corporate farming and reduced grower numbers will also result in changes to the way vegetable crops are irrigated. Larger farm units are typically characterised by increased levels of automation and mechanisation. New large-scale vegetable-growing operations typically involve fully automatic watering systems, such as drip or solid set spray irrigation systems (which operate at relatively low pressures) with automatic control valves to switch between blocks. For crops such as potatoes and carrots, moveable centre pivots are now used where once the less water-efficient travelling gun irrigators or fixed set overhead sprinklers (which operate at relatively high pressures) were the systems of choice. Sophisticated soil moisture monitoring tools and flow meters on pressurised systems are more likely to be used on large farms, as are the services of specialist agronomists and irrigation consultants. The net result is improved water use efficiency in terms of more tonnes of product for every megalitre of water used. More flexible water trading arrangements under water reforms in certain valleys could also favour further investment in large scale vegetable enterprises.

A trend that may be occuring in more than one vegetable-growing region is a resistance to invest in more efficient irrigation technology due to the enterprise being located close to an expanding urban centre. Growers are waiting for housing or industrial developers to buy their properties so that they can retire, and they are therefore reluctant to invest in technology that would allow them to use recycled water or improve their water use efficiency and quality. This expansion of urban and industrial spaces may result in entire districts 'disappearing', causing a shift to production areas that are more distant from capital cities, resulting in higher transport costs. The ability to secure larger farms or contiguous fields in these production areas may allow for efficiencies that outweigh the higher transport costs.

In response to water shortages, extension/incentive programs, and production imperatives, many vegetable producers have adopted irrigation scheduling devices, whether simple (e.g. tensiometers, gypsum blocks) or complex (e.g. capacitance probes, logging matrix sensors). Rates of adoption are associated with the presence of advocates and back-up service, reliability of devices, incentive programs (e.g. Rural Water Use Efficiency Initiative in Queensland), and user awareness and skill-building programs.

A major component of the Queensland RWUEI and the NSW Irrigation and Drainage Management Plan (IDMP) programs has been irrigation system evaluation and recommendations for improvement or change. Examples are changing pump configurations and performance to improve energy efficiency to more closely match system requirements. This has been particularly common where producers have moved from high pressure systems, such as hand shift sprinklers or travelling guns, to low pressure booms or drip.

Another common response to an adverse evaluation is reconfiguration of sprinkler systems following assessment of low distribution uniformities from current designs and equipment. The responses include reduced lateral spacing in solid-set sprinkler designs to improve overlap, changing sprinklers to more wind-resistant heads, or changing sprinkler or boom nozzles to match irrigation output with soil infiltration rates.

Due to the impact of recent severe droughts, there has been a significant increase in utilisation of drip systems for vegetable production. In many solanaceous and cucurbit crops, these systems have been common since the late 1980s, but recently the use of drip irrigation has expanded to crops such as potato, sweetpotato, onions, lettuce, brassicas, beans and sweet corn. The move to drip irrigation is often accompanied by more automation of irrigation controllers.

Irrigation efficiency improvement programs require some extension support, either from a government service, or private industry such as a processor (such as Simplot). As public sector extension is gradually wound back in Australia, the vegetable industry will need to look at alternative means of providing such technical information to growers if it is to seriously address continuously improved water management in the larger regional vegetable production areas.



8. RECOMMENDATIONS FOR FUTURE RESEARCH

Based on analysis of information in the state reports, and discussion with industry at a local level, the authors have compiled the following recommendations for areas of future research in water which would benefit the vegetable industry, and for which industry funding through Horticulture Australia, AUSVEG or other sources could be applied.

8.1 ECONOMICS OF WATER

1. Conduct regular analysis of industry trends and issues, similar to the HAL/Growcom study *Economic contribution of horticulture industries to the Queensland & Australian economies* (CDI Pinnacle Management & Street Ryan and Associates 2004).
2. Develop whole farm economic models that incorporate overheads and operating costs, and fluctuating water, yield and price scenarios, as tools to enhance the evaluation and comparison of vegetable enterprises and industries, and impacts of changing technologies and external environments on net farm cash income, farm operating surplus, and business returns on equity at farm level. The value of owner/operators time needs to also be recognised.
3. Develop clear economic drivers to support improved irrigation management. Include published benchmarks of economic return per megalitre relevant to the main vegetable crops and a clear demonstration of potential to improve return per megalitre applied.
4. Develop a program to regularly update regional vegetable crop gross margins, as the fundamental building block for enterprise/industry analysis. At the same time, investigate technical reasons for differences in water use efficiency indices between regions for like crops.
5. Conduct a detailed study of the threshold cost of water, beyond which vegetable growing becomes uneconomic. For instance, in the Lachlan Valley in NSW in 2004/05, it was 'guesstimated' that up to $400/ML could be paid for temporary water before it became unfeasible to grow vegetables. This is particularly important where limited resources of good quality water are driving higher land and water prices.
6. Investigate the feasibility and consequences of on and off farm water recycling. Significant intensive vegetable growing is centralised around urban centres across Australia, in prime position to utilise urban produced recycled water resources, and where joint government and business investment can be harnessed for efficient and sustainable water use.
7. Develop more quantitative data on product quality improvements which can be achieved through use of highly efficient irrigation systems such as subsurface drip. Assuming this translates into better product prices in the market, it will be a strong driver for adoption of highly water efficient delivery systems and irrigation timing in the vegetable industry, and can be developed through joint investment from the manufacturer and vegetable industry.
8. Seek, where water savings are achieved on-farm, to return those savings to the community through schemes such as the replacement of open channel systems with piping to reduce transmission losses. This will require the vegetable industry to work through all levels of government, irrigator associations and local water companies.

8.2 BENCHMARKING, TECHNOLOGY AND TRAINING

9. Conduct extensive benchmarking of water use in the major crops, as present data is inaccurate, or relevant only to specific regions. Encouragement for growers to install flow meters on their pressurised water delivery points to farm and crops would be an excellent start. Benchmarking should be focused on particular factors (e.g. irrigation type, crop, soil, region) and needs to be conducted over a sufficient interval to allow meaningful comparisons to be drawn. Metering water use is already compulsory in some growing regions and has facilitated effective resource use and monitoring of pump and irrigation systems for optimum performance. Installation and monitoring of on-farm testwells has also proven an effective learning tool amongst groups in catchment areas, and provides a wider regional measure of water management.
10. Develop recommendations to better manage field variability in terms of yield and product quality and its impact on productivity, water use, and dollar return per megalitre.
11. Extend current irrigation scheduling and irrigation efficiency knowledge and demonstrate best practices for vegetable growers to increase the percentage of establishments using irrigation scheduling (currently 39.9% for all horticulture) and using management practices which account for reduced water allocations under drought.
12. Provide guidelines that vegetable producers, catchment managers and environmental protection agencies can readily adopt to assist them effectively and sustainably use alternative water sources, such as recycled water, or non-potable aquifers.
13. Support irrigation efficiency training and demonstration, particularly skills training to manage 'new' types of irrigation systems, scheduling tools and crop/soil management on a wider range of soil types than traditionally irrigated throughout Australia.
14. Use economic case studies of leading vegetable irrigators as 'showcase' examples of what is being achieved throughout the industry, with irrigation system suitability and benefit–cost analyses included in these studies. Present these case studies to the wider media in order to raise awareness of industry advances in irrigation management, productivity per unit of water and water use efficiency.

8.3 RELIABLE INDUSTRY DATA

15. To be less dependent on the ABS, AUSVEG could collect independent statistical production data. Growers would have more confidence in the security of data they provide to their own industry than what they provide to a government body. To resolve the issue of inaccurate industry data, AUSVEG could then relate the ABS statistics to actual field data and coordinate to get a better quality of statistics, which do not completely rely on grower's statements and also take into account 'unofficial' products.
16. Investigate methods to increase collection frequency of consistent, reliable, verifiable volumes and prices of production inputs and outputs for vegetable industries across Australia.

APPENDIX: AN ECONOMIC ASSESSMENT OF THE ADOPTION OF IMPROVED IRRIGATION TECHNOLOGIES IN THE AUSTRALIAN VEGETABLE INDUSTRY

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1 BACKGROUND

Most irrigation areas in Australia are experiencing problems of deep drainage, rising watertables, soil salinity, and excessive amounts of chemicals in the drainage water. Also, the current water reforms include provision for diverting water from agriculture to the environment and for the maintenance of river health and this has led to less water being available for irrigation, with potentially serious repercussions on profitability and economic viability of different agricultural industries.

Although the vegetable industry is considered to be more efficient compared with most other agricultural industries in terms of water use efficiency and profitability, stiff competition in the local and international markets has resulted in declining farm profits, and economic sustainability is under serious threat. This is evident from the fact that the number of vegetable farms has declined over time but the farm size has increased. Vegetable farming is very labour-intensive, with labour costs being one of the major components of total variable costs. Furthermore, most of the vegetable farms have limited water supplies due to reduced general security allocations. Therefore, vegetable growers are being encouraged to upgrade their current less efficient irrigation systems to more efficient, 'high tech' irrigation systems to help improve productivity, profitability, water use efficiency and labour savings in the vegetable industry.

Installation of different 'high tech' irrigation systems like centre pivot and drip involves significant initial capital investment, replacement and maintenance costs. Depending upon crop type, the farmer's management skills, the availability of labour, and the pricing and marketing arrangements in place, irrigation systems perform differently when growing different vegetable crops. It is important, before recommendations are made to the farmers, to know the type of irrigation technology most suited to a particular vegetable crop and the benefits of switching over to a 'high tech' irrigation system compared with the costs involved in the installation of such systems.

One of the aims of this project on maximising returns from water in the Australian vegetable industry, funded by Horticulture Australia Limited, was to identify irrigation technologies most suited for different vegetable crops. The study has considered several farm-level case studies to identify irrigation technologies most suited to different crops grown in vegetable growing regions in Australia.

The main objectives of the economic analyses were to measure the potential economic and environmental benefits of conversion from an existing, less efficient irrigation system to a new, more efficient irrigation system on several selected case study vegetable farms (different crop types in different vegetable-growing regions in Australia).

More specifically the aims of the economic analysis were:

- to measure potential financial benefits to farmers from different remedial measures;
- to identify the economic and environmental benefits from adopting a more efficient irrigation system; and
- to compare benefits with the costs involved in adopting different improved technologies.

Sophisticated irrigation systems involve significant initial capital investment, and the stream of benefits flow over the life of a system (15 to 20 years). To measure returns from the on-farm investment in such technologies, the benefits from a new system were measured, taking into account the total impacts of the option: improvement in yield, quality, shifts in cropping rotation, reduction in input costs, labour savings, water savings and social and environmental benefits. Similarly, the study considered different costs involved, such as capital cost, installation costs, operational costs, repair and maintenance costs and replacement costs, for a particular farm.

2 METHODOLOGY

2.1 FEATURES OF ECONOMIC ANALYSIS

The analysis involves a partial budgeting approach in which the additional and foregone annual costs and benefits of an option were compared. The analysis was carried out from both a financial and an economic perspective.

A **financial evaluation** was undertaken in order to ascertain the attractiveness of the option from the perspective of the farmers. In undertaking a financial evaluation, it is appropriate to use financial values for all relevant inputs and outputs. 'Financial values' refer to the prices/benefits actually received by farmers for outputs or actually paid by them for inputs or losses suffered by farmers.

Economic analysis considers the total impacts of the option, both direct and indirect. Economic values also correct any distortion in the financial values due to government intervention (e.g. taxes or subsidies on inputs) or to the market power certain producers may exhibit (e.g. monopolies).

The period over which benefits and costs of the proposal were accounted for in calculating present values of costs and benefits was 20 years from year 2005. It is anticipated that the effective life of most of the 'high tech' irrigation systems is 20 years. Although some irrigation systems may last longer than 20 years, the costs involved in repair and maintenance and replacement of some of the components such systems are so huge, it is considered to be economical to replace the old irrigation system with a new system.

Two criteria were used in assessing the financial and economic merit of the conversion: the **net present value (NVP)**, and the **benefit–cost ratio (BCR)** of the proposal.

The net present value is described as the difference between the present value of costs associated with the proposal and the present value of benefits accruing from the proposal. The proposal is deemed to have a positive impact if its NPV exceeds zero.

The benefit–cost ratio is the ratio of the net present value of total benefits and the net present value of total costs. The proposal is deemed to have a positive impact if the BCR exceeds unity.

A real discount rate of 4 per cent per year has been used in undertaking an economic evaluation of proposals. It ensures that all future costs and benefits will be measured in relation to the current purchasing power of money and that any inflation of future costs and benefits will not distort the results.

Risk is an important component of the production environment. Different enterprises will have different levels of associated production and price risks. Sensitivity budgets developed with respect to yield and prices may help vegetable growers and industry to understand the effect of these variations on returns to investment in such conversions.

2.2 VALUE OF INCREASE IN CROP YIELD OR QUALITY

Improved irrigation technologies that help improve water use efficiency (WUE) also lead to increased crop yield or higher output price due to better product quality. The improvement in quality or yield would increase gross returns from a crop but would also involve some additional costs in harvesting, transporting and marketing additional quantities of the output. Therefore the benefits from yield or quality improvements are worked out through the increase in gross margins from a crop.

2.3 VALUE OF WATER SAVED

At the farm level, there are a number of choices concerning any water saved as a result of reduction in water use due to efficient use of water. Farmers may choose to use the saved water in increasing the area under different crops, or carry over this water to the next irrigation season, or sell any water saved. In these evaluations, we assume that the value of saved water is the price it could be sold for. Market value of water in different irrigation areas would vary depending upon the availability of water and supply of water to vegetable farms i.e. surface water, regulated or unregulated supply of water, river pumping or bore pumping, and so on.

2.4 VALUE OF LABOUR SAVED

Growing vegetables using less efficient irrigation technologies requires the farmer to spend time on many different irrigation operations. The adoption of 'high tech' irrigation technologies for growing vegetables helps save labour. The saving of farmer's time on different irrigation operations is valued at a basic rate of $25 per hour.

2.5 ENVIRONMENTAL BENEFITS

There are expected to be some benefits to the broader Australian community from the adoption on vegetable farms of improved irrigation technologies that, due to improved WUE, help prevent deep drainage of water.

It is difficult to directly measure the benefits of a reduction in groundwater accessions. One method is to consider the cost of pumping out 1 megalitre of groundwater, where the area has suitable aquifers. Whilst it is unlikely that spearpoints could remove all of this water, a cost of $43/ML for pumping out groundwater has been used as a surrogate measure of the benefits of reducing groundwater accessions. This includes the cost of pumping out.

The reduction in groundwater accessions would also lead to a reduction in irrigation salinity. It has been found that irrigation salinity leads to a loss of infrastructure. The study has assumed the value of $15/ML in reduction in loss of infrastructure due to salinity as an economic benefits to the community (Singh 2005).

3 OVERVIEW OF THE CASE STUDIES

Returns to investment on the conversion to more efficient irrigation technologies from different existing, less efficient technologies were measured for the three case study farms growing different vegetables in different regions and states of Australia. Details of the case studies considered for the economic analysis are given in Table A1.

Table A1 – New irrigation technologies by type, and location of case study farms

	New irrigation technology	Existing irrigation system	Type of case study vegetable farm	Location/region
Case study 1	Centre pivot	Travellers	Sweet corn	Bathurst, NSW
Case study 2	Drip	Furrow irrigation	Tomatoes	Echuca, Victoria
Case study 3	Drip irrigation	Overhead sprinkler	Broccoli	Queensland

Since the existing irrigation systems are being replaced with different new irrigation technologies that involve different capital and maintenance costs, and lead to different benefits for different crops, the study analyses the returns to investment for each farm separately.

CASE STUDY 1: TRAVELLER → CENTRE PIVOT, SWEET CORN

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To measure benefits and costs involved in the conversion to centre pivot from an existing traveller irrigation, a vegetable farm belonging to Jeff McSpedden, located at The Lagoon, 20 km from Bathurst on the Central Tablelands in NSW, was selected as an irrigation technology case study farm. The soils of the farm are of friable black loam to clay loam overlying medium black clay loam (prairie soil) and are suitable for growing vegetable crops. The farmer grows 100 ha of area under different vegetable crops, mainly sweet corn, broccoli, radicchio and lettuce. Irrigation water is used directly from the Campbell River downstream from Chifley Dam.

A traveller irrigation system was being used to irrigate 34 ha of sweet corn crop (Super Sweet, for processing). The existing system was not efficient in terms of uniform application of water to the crop, leading to low crop yields and poor quality of corn, and attracting lower prices due to some crop being rejected because of poor quality.

To improve yield, quality and water use efficiency, Jeff McSpedden decided to replace the existing traveller with a new centre pivot, a more efficient irrigation technology, to irrigate the same size and type of crop.

In the economic analysis, the information on crop yield, prices received, input use, water and labour used and capital and operating costs and so on for both the systems is based on the farmer's records and accounts. To fill a few gaps in the data required for the analysis, information was collected through personal discussions with the local irrigation and industry people and the technical staff involved in the project.

The information on crop yield, prices, water volumes, water costs, input use, water losses through surface and subsurface drainage, capital costs, installation and other maintenance costs and expected life of different components of both irrigation systems is given in Tables A2, A3 and A4.

Table A2 – Operation area, crop yield and market price of sweet corn for centre pivot and traveller

		Traveller	Centre pivot
Total area covered	(ha)	34	34
Area under roads	(ha)	0.5	0.25
Operational area	(ha)	33.50	33.75
Crop yield	(t/ha)	16	19.2
Market price	($/t)	$168.00	$192.50

Table A3 – Water usage, water and labour costs and water losses through seepage and surface run-off for traveller and centre pivot, sweet corn production

		Traveller	Centre pivot
Water used	(ML/ha)	3.0	2.5
Water costs	($/ML)	$10.00	$10.00
Running electricity costs	($/ha)	$67.00	$17.00
Labour costs	($/ha)	$130.00	$32.00
Water losses through seepage	(%)	15%	0%
Surface run-off	(%)	20%	5%

Table A4 – Capital, installation and maintenance costs for traveller and centre pivot systems

		Traveller	Centre pivot
Cost of irrigation system	($)	$32 000.00	$84 000.00
Life of the system	(years)	20	20
Cost of pipes	($)	$6 900.00	$14 000.00
Crop life of pipes	(years)	40	40
Cost of hydrants	($)	$2 500.00	
Cost of head works	($)		$1 000.00
Cost of tyres	($/year)	$500.00	$3 000.00
Life to tyres	(years)	5	5
Other maintenance cost	($/yr)	$300.00	$300.00

Both systems were used to irrigate 34 ha of sweet corn crop. Although initial capital costs are much higher in the centre pivot than in the traveller, centre pivot is found to be much more efficient in terms of crop yield, price, use of area, water and labour use and reduction in water losses compared with the traveller irrigation (Tables A2, A3 and A4).

TECHNICAL AND FINANCIAL IMPACTS OF CONVERSION

It has been found (Table A5) that adopting the centre pivot leads to an increase in the crop yield by 20%: that is, from 16 tonnes per hectare under traveller to 19.2 tonnes per hectare using centre pivot irrigation. Furthermore, the uniform application of water helps to improve the quality of sweet corn. It is assumed that there would be a $26.00/t premium on 25% of the crop yield, i.e. on average $6.50/t for 19.2 t/ha of the crop (personal communication, Mark Hickey). The increase in yield involved an additional harvesting cost of $51/ha, therefore the net benefit from yield and quality improvements was $565.00/ha.

Table A5 – Financial benefits of conversion from traveller to centre pivot

Measure		Value
Increase in yield	(t/ha)	3.2
Price premium on quality	($/t)	$6.25
Water saved	(ML/ha)	0.5
Value of water saved	($/ML)	$50.00
Value of electricity saved	($/ha)	$50.00

The new irrigation system also used 0.5 ML/ha less water to irrigate the crop (Table A6), thus improving the water use efficiency by 20%. This not only helped to reduce the cost of production, but the saved water was an extra source of income for the farmer.

Table A6 – Economic benefits of conversion to centre pivot irrigation

Measure		Value
Reduction in deep drainage	(ML/farm)	15.1
Reduction in loss of water though service run-off	(ML/ha)	0.5
Reduction in losses to infrastructure due to salinity	($/ML)	$5.00
Value of reduction in seepage losses	($/ML)	$43.00

VALUE OF WATER SAVED

In the regulated river supply system, the water trading price varies inversely with the availability of water. For example, in the MIA the water price ranges from $30.00/ML when allocations are up to 80 percent, to $50.00/ML at 50 percent availability and $70.00/ML at 30 percent water availability (Singh 2005). It is assumed that the average annual water allocation may only be around 50 percent of the total annual water entitlement of a broadacre rice farm (personal communication John Lacy). Therefore a price of $50.00/ML has been considered as a surrogate value of water saved on the case study farm.

ENVIRONMENTAL BENEFITS

The improved water use efficiency would help to reduce losses through deep drainage and surface run-off. The conversion to centre pivot would help prevent losses of 15.1 ML and 17 ML of water to deep drainage and surface run-off respectively.

BENEFIT–COST ANALYSIS

The results of the benefit–cost analysis presented in Table A7 show that the present value of benefits, present value of costs and the net present value of the financial benefits from adopting improved technology were $330 000.00, $45 500.00 and $284 000.00 respectively.

The benefit–cost ratio of 7.2 indicates that every dollar spent on the improved technology leads to a $7.40 increase in income. Economic benefits that take into account the environment and community benefits were even higher, and therefore the adoption of centre pivot on the selected farm is viable from both the financial and the economic perspectives. Furthermore, the study found that converting to centre pivot irrigation helped the farmer receive an extra benefit of $31 000 through an increase in yield, area under cropping, value of water and labour saved, so he was able to recover the additional costs of $45 500 involved in conversion to a centre pivot irrigation system in the second year.

Table A7 – Results of the benefit–cost analysis

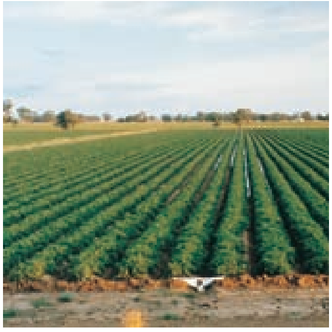
Measure	Financial analysis	Economic analysis
Present value of benefits	$330 000.00	$338 000.00
Present value of costs	$45 500.00	$45 500.00
Net present value	$284 000.00	$292 000.00
Benefit–cost ratio (%)	7.2	7.4

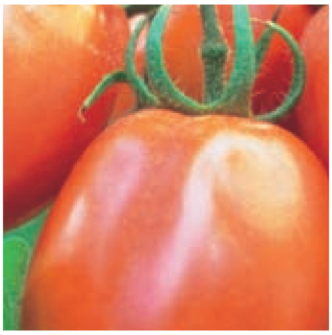
SENSITIVITY ANALYSIS

Better irrigation management increases crop yield or quality of the product, or both. There are some incentive payments made for higher quality sweet corn. Sensitivity analysis was undertaken to analyse the effect of variations in increase in crop yield and quality premium on total benefits from conversion to centre pivot. The results of the sensitivity analysis presented in Table A8 reveal that the returns from the investment are more sensitive to increase in yield than the premium received through quality improvements.

Table A8 – Sensitivity to variations in yield and quality premium from adoption of centre pivot irrigation

Measure		Financial analysis	Economic analysis
Yield	No increase in yield	3.2	3.4
	10% increase in yield	5.2	5.4
Premium	No premium	6.3	6.4





CASE STUDY 2: FURROW IRRIGATION → DRIP IRRIGATION, PROCESSING TOMATOES

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BACKGROUND

One of the farms of Gerard Ryan and Sons, vegetable growers, located in Rochester in Victoria, was selected for measuring the economic benefits of conversion to drip irrigation from existing furrow irrigation for growing processing tomatoes.

The farm is mid-way between Rochester and Echuca, just west of the Northern Highway. It is 200 ha, with Rochester clay soils suitable for growing vegetables and other winter crops such as cereals and fodders. In all, the grower uses 384 ML of water, of which 60 ML is used for growing wheat and the rest for growing processing tomatoes. Until 2003–04 he was growing processing tomatoes using only furrow irrigation. He has set up a recycling system that helps to use irrigation water on furrow-irrigated crops more efficiently and prevent any loss of water through deep drainage or surface run-off.

In 2004–05, he decided to install drip irrigation on a 24 ha block of land to grow processing tomatoes in addition to 24 ha of tomatoes he was growing using furrow irrigation. The drip irrigation was put together from salvage parts, second-hand pipes and some new components, and, by spending a lot of time and effort in assembling these parts for drip irrigation, he was able to save a significant amount of money. Although the drip irrigation is not as efficient as a fully automatic new irrigation unit would be, it has helped to increase farm income, save labour, and improve water use efficiency in growing tomatoes on drip-irrigated areas of the farm.

The aims of the study were to analyse potential benefits and costs involved and measure returns to investment on the drip irrigation for growing processing tomatoes on the case study farm.

DATA AND ASSUMPTIONS USED

As mentioned earlier, the drip irrigation block was set up during 2004–05 using salvaged components. All the water supplied to the two blocks selected for growing tomatoes goes through one wheel.

Only limited information was provided by the farmer, and that pertains to 2004-05 only. Production and financial data are lacking in terms of crop yield of tomatoes and wheat over the length of the cropping rotation, water use, capital costs involved, and so on.

In this analysis, some of the information used for measuring benefits and costs involved in conversion to drip irrigation on the selected farm is based on the farmer's records and accounts. To fill gaps, especially on crop yield, input use, capital and operating costs involved in both systems, information was collected through personal discussions with irrigation and industry people and the technical staff associated with the project. Some of the data used in the analysis is based on the findings of a study 'Best management guidelines for irrigation of processing tomatoes' (Ashcroft et al. 2001).

The information on cropping rotations, crop yields and gross margin of different crops used in the analysis is given in Tables A9, A10 and A11.

CROP ROTATIONS CONSIDERED

To compare the performance of the two selected irrigation technologies, two adjacent blocks, each of 24 ha, were irrigated with drip and furrows respectively. The farmer follows a six-year cropping rotation on both furrow- and drip-irrigated paddocks. In the furrow-irrigated paddock, he grows two crops of tomatoes followed by four crops of wheat or other winter crops or pastures, whereas in the drip-irrigated paddock he grows tomatoes for three years followed by three years of wheat or other crops or pastures (Table A9).

Table A9 – Cropping rotations on the selected blocks of the case study farm

Type of irrigation	Crop rotation					
Furrow irrigation	T	T	W	W	W	W
Drip irrigation	T	T	T	W	W	W

Note: T – tomatoes, W – wheat

Although the yield of processing tomatoes both from the drip- and furrow-irrigated paddocks declined in the second and third years, with the better irrigation management, the yield from the drip-irrigated tomato crop increased by 30 percent in year 1 and 27 percent in year 2 compared with the tomatoes grown in the furrow-irrigated paddock. Drip irrigation also enables the farmer to grow an additional crop of tomatoes compared with the wheat grown in year 3 in the furrow-irrigated paddock. This helps the farmer to get more than $3000 per hectare of extra income in the third year of the rotation from the drip-irrigated paddock over the furrow-irrigated paddock (Tables A10 and A11).

Table A10 – Furrow-irrigated paddock, yield and gross margins of crops

Year	Crop	Yield (t/ha)	GM ($/ha)
1st year	Processing tomatoes	81	$4 080
2nd year	Processing tomatoes	75	$3 619
3rd year	Wheat	4	$222
4th year	Wheat	4	$222
5th year	Wheat	4	$222
6th year	Wheat	4	$222

Table A11 – Drip irrigation, yields and gross margins from different crops

Year	Crop	Yield (t/ha)	GM ($/ha)
1st year	Processing tomatoes	105	$6197
2nd year	Processing tomatoes	95	$5334
3rd year	Processing tomatoes	81	$4126
4th year	Wheat	4	$222
5th year	Wheat	4	$222
6th year	Wheat	4	$222

Other inputs used in the gross margin analysis were derived from the farm budget handbook for different vegetables (NSW Agriculture 2001). Similarly, the 2005 gross margin budgets for irrigated wheat developed for the Murrumbidgee Irrigation Area in southern NSW were used in the analysis.

It was found that drip irrigation helped to improve water use efficiency in growing processing tomatoes. The water used to irrigate tomatoes on the selected blocks was not monitored separately because all the water supplied was through one wheel, so the figure for the water used per hectare for growing tomatoes was worked out from the information provided by the grower on the average application rate, irrigation interval and the number of shifts required per irrigation (Table A12).

Table A12 – Average application rate, number of shifts and irrigation interval on furrow and drip irrigation for growing processing tomatoes

	Furrow irrigation	Drip irrigation
Average application rate	Delivery from wheel at 8 megalitres per 24 hours (i.e. 0.33 ML/h)	Drippers specified at 1.55 L/h and spaced at 50 cm on 1.5 m beds, which is 2.07 L/m^2/h
Number of shifts required/ irrigation	3 (12-hour shifts every 4 days at peak)	2 (daily shifts totalling 4 hours per day per block)
Irrigation interval	96 hours (every 4 days)	24 hours (daily)

To grow tomatoes with furrow irrigation, irrigation is applied after four days from fruit setting to harvesting stage. The irrigation interval will be longer when the plant is younger. Based on the information given in Table A12, it is estimated that 5.4 ML/ha and 8.4 ML/ha of water were used to grow tomatoes in drip-irrigated and furrow-irrigated blocks respectively (Table A13).

Output prices, water volumes used, water costs, market value of water and labour used to grow tomatoes are given in Table A13.

Table A13 – Water use, labour requirements, market value of water used and price of tomatoes

	Furrow irrigation	Drip irrigation	
Total water applied (ML/ha)	8.40	5.40	
Water costs ($/ML)	$60.00	$60.00	The cost of irrigation water used in the analysis is $60/ML.
Labour for irrigation operations (h/ha)	7.50	3.75	The grower spent 7.5 hour/ha on the furrow-irrigated block and 3.75 hour/ha on the drip-irrigated block.
Price of tomatoes ($/t)	$95.00	$95.00	

The price of processing tomatoes depends upon the concentration of soluble solids in the fruit. A grower will get a higher price if the concentration of soluble solids is higher than the industry average of 4.9 percent. Similarly he will get a lower price if the concentration of the soluble solids is less than the industry average. In general, the concentration of the soluble solids in tomatoes declines with the increase in crop yield. Due to a lack of information on the impact of increase in yield from drip-irrigated tomatoes, the same price of $95 a tonne was used in this analysis.

COSTS INVOLVED IN THE ON-FARM RECYCLING SYSTEM

The costs of construction, operating and maintenance costs of recycling system used to recycle water in furrow-irrigated paddocks is given in Table A14.

Table A14 – Expenditure involved in recycling system used with furrow irrigation

Expense	Cost
Cost of recycling system	$15 000
Operating costs	
Diesel used for recycling system (L/year)	8 000
Cost of fuel ($/year)	$5 440
Repair and maintenance ($/year)	$100

The farmer has set up an on-farm recycling system that helps to apply furrow irrigation more efficiently, thus preventing water losses through deep drainage and surface run-off. He is using a diesel pump and spends more than $5000 per year on fuel to run the pump for recycling the water from the furrow-irrigated block (Table A14).

COST OF DRIP IRRIGATION

The costs of assembling drip irrigation, operating, repair and maintenance, and replacement are given in Table A15.

Table A15 – Capital costs, operating costs, maintenance and replacement costs involved in involved in drip irrigation

	New system	Used system
Capital costs	$85 000	$50 000
Repair and maintenance ($/ha)		
1st year	$0	$0
2nd year	$200	$200
3rd year	$400	$400
Replacement costs	$40 000	$20 000
Expected life (years)	30	18

As stated earlier, the farmer has assembled the drip irrigation himself using both new and salvaged components, and so the total cost of the drip irrigation is not possible to calculate. The estimated cost of this drip irrigation was $50 000 and the life of the system will be 18 years. The farmer would spend $20 000 after 6 years to replace some of the components (personal communication, Robert Hoogers).

Furthermore, it is estimated that the cost of a new system of the same size and with the same amount of time committed by the farmer would be $85 000. The expected life of a new drip would be 30 years; it would require an additional cost of $40 000 to replace some components after 20 years. It would also involve a repair and maintenance cost of $200 in the second year and $400 in the third year, which includes the cost of ripping and relaying the submains and drip tape and tubes in another paddock after three years (Table A15).

BENEFIT–COST ANALYSIS

The study considered three scenarios to measure the additional benefits and costs involved in the use of drip irrigation for processing tomatoes on the case study farm.

Scenario 1

1. The farmer has installed drip irrigation using mainly salvaged components.

2. To compare the performance of the two selected irrigation technologies, two adjacent blocks each of 24 ha were irrigated with drip and furrow respectively. The farmer does not move the drip to another paddock after the tomato phase of the rotation. He grows 3 years of tomatoes and 3 years of wheat on a block with drip irrigation and 2 years of tomatoes and 4 years of wheat on the 24 ha block using furrow irrigation.

24 ha under drip irrigation
T
T
T
W
W

24 ha under furrow irrigation
T
T
W
W
W

Scenario 2

1. The farmer has installed drip irrigation using mainly salvaged components.

2. Two adjacent blocks each of 48 ha are irrigated with drip and furrow respectively. In the furrow-irrigated area every year he grows 16 ha of processing tomatoes and 32 ha of wheat, whereas he grows 24 ha of tomatoes every year in the drip-irrigated field. He moves to the other block to grow tomatoes every 2 years in the case of furrow and every 3 years in the case of drip irrigation. This will involve an additional cost of ripping and relaying drip irrigation to another block every three years.

48 ha under drip irrigation	
24 ha	24 ha
T	W
T	W
T	W
W	T
W	T

48 ha under furrow irrigation		
16 ha	16 ha	16 ha
T	W	W
T	W	W
W	T	W
W	T	W
W	W	T

Scenario 3

1. The farmer has installed the drip irrigation using new components.

2. Two adjacent blocks each of 48 ha are irrigated with drip and furrow respectively. In the furrow-irrigated area every year he grows 16 ha of processing tomatoes and 32 ha of wheat, whereas he will grow 24 ha of tomatoes every year in the drip-irrigated field. He moves to the other block to grow tomatoes after every two years in case of furrow and after every 3 years in case of drip irrigation. This will involve an additional cost of ripping and relaying drip irrigation to another block every three years.

Results and discussion

The results presented in Table A16 indicate that the investments made by the grower to install drip irrigation have been a sound investment. He receives $6.80 and $12.09 and $10.62 for every dollar invested in the improved irrigation technology using salvage parts (Scenario 1 and Scenario 2) and new components (Scenario 3) respectively.

Table A16 – Benefit–cost analysis of adoption of drip irrigation on the case study farm

Measure	Scenario 1	Scenario 2	Scenario 3
Present value of benefits	$418 600	$802 900	$1 096 700
Present value of costs	$65 500	$70 700	$104 200
NPV benefits	$353 100	$732 100	$992 500
B/C ratio	6.39	11.35	10.52

SENSITIVITY ANALYSIS

Sensitivity analysis was used to demonstrate the effect on returns of changes in crop yield, output prices and discount rate. Output prices are based on incentive payments made for higher total soluble solids tomatoes. The current base level for total soluble solids (TSS) is 4.9%, with an average incentive of $2.60 for every decimal point increase in TSS.

The results of the sensitivity analysis revealed that the returns from the investment are sensitive to price and crop yields and the discount rate used in the analysis (Table A17).

Table A17 – Sensitivity of results to changing value of selected parameters

		Scenario 1	Scenario 2	Scenario 3
Yield response (t/ha)	10% less than current yield (both)	5.38	9.55	8.85
	10% more than current yield (both)	7.19	12.78	11.85
	10% more than current yield (drip only)	7.06	12.52	11.61
Output prices ($/t)	10% more than the current price (both, for high TSS)	7.93	14.06	13.04
	10% less than the current price (drip only, for higher TSS)	5.63	10.00	9.27
Discount rate (%)	7%	5.40	9.77	8.53
	10%	5.01	8.57	7.08

Growers are rewarded for higher quality fruit (i.e. high total soluble solids content), and, while it is possible to achieve high solids content using drip irrigation, high-yielding drip-irrigated blocks have tended to have low TSS levels. Improvements in nutritional and irrigation management are producing better results with drip. The incentive payment system introduced by the processors during the 1990s for higher solids fruit has encouraged growers to achieve a balance between yield and solids. Thus the sensitivity analysis shows that, while there are slightly better returns for the grower by increasing crop yield, growing for higher solids content can provide significant benefits to the grower.

CASE STUDY 3: SPRINKLER → DRIP IRRIGATION, LETTUCE AND BROCCOLI

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[2] Queensland Department of Primary Industries and Fisheries, Brisbane, Queensland

BACKGROUND

Grower – Max Durham is a major lettuce, broccoli and capsicum producer in the Lockyer Valley, Southern Queensland. He farms approximately 300 ha of alluvial black earth soils both by the banks of Lockyer Creek, and on surrounding leased land. He has been using overheads to irrigate different vegetable crops.

By 2003/04, after consecutive years of drought and below average rainfall in the Lockyer Valley, water levels in the aquifer supplying irrigation to the farm had dropped to the lowest levels ever across much of the farm. Faced with this potential water shortage, Max stopped using turbine pumps down bores, replaced them with submersibles, and built three turkeys nest dams for storing water. With the existing overhead sprinklers, the available water was not sufficient to produce vegetables to meet his long-term market commitments.

His initial response was to consider markedly reducing the area under vegetable cropping. This would have meant losing market access (retail chains, processing factories), built up over 15 years, and not easily recovered once lost.

In order to retain his market access, he decided to change from overhead sprinkler irrigation (solid-set or hand-shift) to drip irrigation: this would help in reducing the per hectare use of water and thus increase the area that could be cropped from the limited water supply. As a result of his switch to drip irrigation, Max was effectively able to increase the cropping area threefold, compared with overhead only.

Overhead sprinklers are still used for the first irrigation after transplanting to establish the transplanted lettuce and broccoli seedlings. Overhead sprinklers can also be used immediately prior to harvest for their cooling effect, if the weather turns unseasonably warm.

The change in systems has helped him to increase the area under lettuce and broccoli substantially.

The objectives of this economic study were to work out the additional costs and benefits from switching over to drip irrigation and to measure the returns on the farmer's investment in adopting drip irrigation.

DATA AND ASSUMPTIONS USED

It is assumed that, in a normal season, when more water is available, the farmer will be able to grow the same area of lettuce and broccoli.

The only savings from his change to a drip system are assumed to be water and fertilisers.

SENSITIVITY ANALYSIS

Information on area sown, input use, crop yield and output prices of broccoli and lettuce grown using overhead and overhead irrigation are given in Table A18.

Table A18 – Area, input use, crop yields and prices of different vegetables grown using different irrigation technologies

	If overhead only:		Drip with start (and finish) overhead:	
	Lettuce	Broccoli	Lettuce	Broccoli
Area sown	25 ha	9 ha	82 ha	28 ha
Yield	3250 cartons/ha	1050 cartons/ha	3250 cartons/ha	1050 cartons/ha
Fertiliser use	100%	100%	50%	50%
Irrigation required (assumes some rain)	2.5 ML/ha	2.5 ML/ha	Winter 0.875 ML/ha Aut/Spr. 1.25 ML/ha	Winter 0.875 ML/ha Aut/Spr. 1.25 ML/ha
Price ($/carton)	$12.00	$16.00	$12.00	$16.00

When growing vegetables with drip irrigation, the cropping season is longer than with overheads. This helped the grower to pump out more water and significantly increased the area under lettuce and broccoli from 34 hectares under overheads to 110 hectares when using drip irrigation.

It was found that the crop yield, output prices and labour requirements were the same but water and fertiliser use declined significantly under drip compared with overhead irrigation (Table A15).

COSTS INVOLVED IN CONVERSION TO DRIP IRRIGATION

Since switching over to drip irrigation has been incremental, both drip and overhead systems use the same mains and submain systems throughout the farm. Where necessary, the hydrants and main pump are throttled back so as not to over-pressurise the drip tape.

Drip tape can only be used for one season, therefore, in the gross margins for drip-irrigated broccoli and lettuce, the cost of 10 000 metres of tape per hectare for lettuce on beds and 6700 m tape/ha for broccoli on 1.5 m beds has been considered.

Details of the capital costs, operating costs and repair and maintenance costs involved in switching to drip irrigation from the existing overheads are given in Table A19.

Table A19 – Capital costs, operating costs, maintenance and replacement costs involved in switching to drip irrigation for growing lettuce and broccoli

Measure	Expenditure
Number of filters required	3
Repair and maintenance ($)	$500.00
Cost of disc filters ($/filter)	$400.00
Number of filters	5
Life of filter (years)	10
Expected life of drip (years)	20
Layflat pipe (metre)	1500
Anticipated life layflat (years)	3
Irrigation scheduling (tensiometer)	$1000.00

To switch over to drip irrigation, the grower invested $60 000 on altering machinery to cope with installation, new bed sizes, drip removal, and so on. The expected life of the machinery is 20 years. It would require an additional cost of $20 000 for major repairs and replacement of some components after 10 years.

The layout requires 3 new sand filters (one for each turkey nest), about $11 000 each; these last 20 years, plus $500 every 5 years to replace sand and maintain. The set-up also requires a set of disc filters every 10 hectares, each costing $400, with a life of 10 years. The study has budgeted for 5 sets only, as not all crop is in the ground at once, and therefore the sets can be used more than once during the season. The system required 75 mm layflat, using 35 metres per irrigated hectare, with an anticipated life of 3 years. The farmer used a total of 1500 metres of layflat for the whole area.

BENEFIT–COST ANALYSIS

The present value of benefits and costs of investment on drip irrigation are given in Table A20. With the present value of benefits at $15.3 million, and the present value of costs at $63 400, the net present value of benefits from drip irrigation is $14.62 million. The benefit–cost ratio is estimated at 24.04.

Table A20 – Results of the benefit–cost analysis of adoption of drip irrigation on the case study farm

Measure	Value
Present value of costs	$63 400
NPV benefits	$14 620 000

The results show that this conversion has been a sound investment. The returns to the farmer's investment have been $24.04 for every dollar invested. The analysis further reveals that the farmer is able to recover the costs of switching to drip irrigation in the first year with a total expenditure of $102 000 and the additional returns from growing different vegetables at $882 000.

SENSITIVITY ANALYSIS

The results of the sensitivity analysis given in Table A21 show that the returns from the investment are more highly sensitive to prices than crop yields used in the analysis.

Table A21 – Sensitivity of results to changing value of selected parameters

	Measure	Value
Yield response (t/ha)	10 percent less than current yield (both)	20.37
	10 percent more than current yield (both)	27.73
Output prices ($/tonne)	10% less than the current price (both)	14.26
	10% more than the current price (both)	33.84

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