Benefits and barriers of converting conventional border irrigation systems to pressurised systems for crops and pastures in northern Victoria: farmers' perspectives

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Abstract. Conventional gravity border check irrigation systems are generally less expensive to install and operate than pressurised irrigation systems and have traditionally been the most common irrigation system in northern Victoria to grow crops and pastures. However, due to high water prices and labour costs, pressurised systems are becoming popular with irrigators, who argue that they increase water use efficiency, decrease nutrient loss and reduce labour costs. The results show that the reasons for conversion varied amongst farmers; however, all identified that they saved water and increased production using pressurised systems. Farmers discussed that energy costs are the major ongoing cost for operation of pressurised systems. The findings of this study can assist extension staff to develop extension packages that could guide irrigators to make informed decisions on the adoption of irrigtion upgrades that meets their needs and generate water savings.

Keywords: extension learnings, irrigation upgrades, pressurised irrigation, water use efficiency

Introduction

Gravity border check irrigation (BC) is traditionally the most common irrigation system used to grow pasture and fodder in northern Victoria. With this system, the fields are divided by low check banks into smoothly graded bays which are approximately 40 m to 80 m wide and 200 m to 800 m long. The longitudinal slope of the bays is between 1:600 and 1:850. Water is applied at the top of the bay through typical farm channel outlets at an inflow rate. At the end of the bays, typical surface drains convey water to on-farm storage dams from where water is pumped for reuse.

A range of factors including drought conditions and increases in water price have encouraged some farmers to convert their conventional BC system to pressurised irrigation systems such as pipe and riser (PR), centre pivot (CP) and subsurface drip (SD) irrigation systems. A PR system includes the distribution of water onto the bay through a network of pipes as opposed to open channels as occurs with a BC system. CP systems are self-propelled sprinkler irrigation systems which apply water to crops, generally from above the canopy. CP systems are anchored at one end and rotate around a fixed central point. SD systems involve the placement of permanent drip tapes below ground surface to supply water directly to the crop root zone.

The process and issues arising from this conversion as well as the benefits and barriers identified by the farmers are the focus of this paper.

Methodology

Interviews were conducted with five farmers who had converted their conventional BC to PR, CP and SD irrigation systems. One farmer has provided information on two of his irrigation systems upgrades. An interview guideline was developed to interview the farmer of each irrigation system. An audiotape was used to record the interviews with the farmers. Irrigators were asked to provide benefits and barriers associated with their old and the new systems. The information presented in this paper is based on their responses and the authors do not guarantee that the information is without flaw of any kind or is applicable to all situations.

Results

This section outlines the responses from farmers who have converted their BC to pressurised systems. For each of the case study farmers, it describes their converted irrigation systems, the reasons for their conversion and their perspectives on the benefits and costs of conversion. The perceived benefits and barriers identified by case study farmers are also summarised in Table 1.

Subsurface drip irrigation system (SD)

Farmer SD1

Background The farmer originally installed SD on 5 ha in 1990 to grow tomatoes. Now his whole farm is under SD comprising 235 ha of lucerne and other crops and 35 ha of horticulture. The farmer grows lucerne, maize, cereals, tomatoes, clover and chickpeas. The predominant soil type is Lemnos loam with the remaining area Shepparton fine sandy loam. The Lemnos loam soil has loam topsoil with a rapid change in texture at approximately 20 cm depth to a clay subsoil which cracks when dry (Skene and Poutsma 1962). The Shepparton fine sandy loam is a relatively permeable soil that is typical of the levees of the prior stream sequence (Skene and Poutsma 1962). The farmer manages the area in 36 blocks averaging 4 to 7 ha in each block. The spacing between drip tapes is 1.5 m which were installed at 20 cm depth. The tape pressure runs at 10 to 15 psi while pressure at the filter is 35 psi. The spacing between the emitters is 0.4 to 0.6 m and the emitter pressure is 5 psi and has a 1.5 litres/hr flow rate. The farmer runs the system with four pumps which have 35 to 38 psi pressure. One of the four pumps is diesel while the others are electric. The farmer uses screen filters to filter the water. In addition to sourcing water from the regional water authority, he also uses water from two irrigation bores. He irrigates the blocks for 24 hours every 4 days or 48 hours every 8 days.

Motivation The farmer's motivation to shift to SD was to increase yield and save on water and labour. Picking up an extra 40 ha of irrigated land was also a driver as this section of the property is undulating and so could not be irrigated with a BC system.

Cost of SD The cost of installing SD was approximately $8,000 to $10,000/ha. The farmer mentioned that the percentage cost to produce 1 t DM/ha of lucerne using SD is:20% water, 20% power, 40% cutting and bailing of lucerne, 3% fertiliser and the remaining factored into maintenance cost.

Maintenance of SD The maintenance cost of the entire SD was $5,000-10,000/year. Water leakage from drip tapes and emitters is the major maintenance issue which was more prominent during the first two years of operation. On average, there are 100 leaks per season, which are generally easy to fix unless there is a major issue, for example, leakage from a cracked sub-main. The farmer occasionally applies acid to clear blocked emitters, however, did not see any difference in crop growth before and after acid application. There was no major pugging (damage of bay surface due to cattle hooves) due to grazing because the soil was compacted enough. To date, the aging of the system has had no major effect on the performance of the system.

Benefits of conversion The farmer reported that he had saved 25% water and increased yield by 30% since converting to SD. Previously the average water use for BC was 8.0 ML/ha to grow lucerne, maize and tomatoes which has reduced to 6.0 ML/ha under SD. The yield using BC was 15, 16 & 60 t DM/ha for lucerne, maize for silage, and tomatoes which were 20, 20 to 25, and 100 t DM/ha respectively under SD. Wood and Finger (2006) reported that water consumption in subsurface drip and sprinkler systems was 2.0 ML less than the border irrigation while maintaining or increasing pasture yield. The farmer identified they had also saved 5% area which was under channels, check banks and fences since conversion and that weeds were less of a problem under SD system.

Overall comments The farmer has been using SD for the past 30 years and others interested in this form of irrigation now approach him for advice. The farmer believes that the SD is a better choice for the growers of this region to save water and labour, increase fertiliser use efficiency and increase yield. The farmer purchased SD parts, design, installation and other information from Netafim, Water dynamics and Admoor companies.

Farmer SD2

Background The total area of the farm is 189 ha out of which 31 ha is SD, 36 ha is CP and the remaining is laid out to PR. The soil type of the farm is Shepparton fine sandy loam. The farmer grazes 175 dairy cows, some head of beef and harvests crop for hay. He grows lucerne under SD and PR and annual crops under CP. The SD is managed in 4 to 7 ha blocks. The spacing of the drip tape is 1.5 m which are installed at 20 cm depth from the surface while the pressure of drip tape is 10 to 15 psi. The farmer uses thicker drip tape because it is stronger and more durable. The emitter spacing is 0.5 m and the emitter pressure is 5 psi which has a 1.5 litres/hr flow rate. He runs SD for approximately ten hours over night on alternate days.

Motivation The area under SD was undulating and was difficult to irrigate by BC. Water losses were higher using BC due to the higher infiltration rates of light soil.

Cost of SD The cost to install SD was approximately $8,000/ha. Power is the main operating cost identified at $200/ha/year.

Maintenance of SD Water losses in SD are rare, however occasionally joints come apart and leakage does occur. There are no major dry patches in the lucerne. Sometimes the farmer applies an acid treatment to clear blockages from the emitters, however, identified that he did not see a major difference in crop growth before and after acid treatment. The farmer does not graze the lucerne to avoid pugging. Overall, the aging of the system has had no major impact on irrigation performance.

Benefits of conversion The farmer uses 30 to 35 ML water for each cut of his 36 ha lucerne block under SD. He cuts lucerne 6 to 7 times in a season which means water used was approximately 6.0 ML/ha in a season. The farmer believes that lucerne yield was 20 to 30% higher using SD compared to BC. The farmer also saves 5% of his overall area with SD which was previously utilised for channels, check banks and fences.

Overall comments The farmer believes that SD has saved water, increased yield and outperformed other systems. He commented that 'if water price rises substantially, I will still irrigate and make money out of SD' To install SD, the farmer sourced information from local growers, manufacturing and installing companies.

Centre pivot irrigation system (CP)

Farmer CP1

Background The total area of the farm is 259 ha out of which 96 ha is under CP and the remaining under BC. The soil type is Shepparton fine sandy loam. Each BC bay is over one hectare in size and the bay outlets are opened and closed manually. The farmer grows a perennial ryegrass clover mix under BC and grazes 400 cows but sometimes cuts the crop for hay.

The farmer purchased his first CP in 2000 and sixth in 2017. The farmer pumps water from an on-farm storage dam. The size of the motor is 45 KW which runs three machines at a time and delivers 7 ML/d flow rate. The farmer operates the machines using a timer due to ease of management. The application rate of each CP is approximately 20 mm/day and based on the crop water requirement, he generally runs the machine for 12 hours over night. Sprinklers on the machines are Senninger wobbler and Nelson series of sprinkler technology. The farmer mentioned that all sprinklers apply the same volume of water, but the distribution of the Wobbler is better. The farmer uses an end-gun for all machines which irrigates an extra one hectare per CP. The farmer grows maize, lucerne, sorghum, ryegrass and a clover mix under CP.

Motivation The farmer has undulating land which is difficult to irrigate using BC. The cost to level the undulating land was $7,000/ha which is higher than purchasing a CP. A CP is also a better choice in this instance due to the high infiltration rate of light soil which can generate substantial deep drainage under BC.

Cost of CP The capital cost of each CP was approximately $3,000/ha. Power is the major cost to operate the system and has been calculated as $25 to pump one megalitre of water.

Maintenance of CP The farmer has spent a total $2,000 on the maintenance of all CP systems till present. The major challenge with maintenance has been trying to identify where the problem is in the machine. The farmer discussed that wheel rutting has not been a major problem.

Benefits of conversion The farmer identified that his maize crop was a good one to use as a comparison as both were grown on the same area (16 ha) under BC and CP. Throughout the season, water use was 8 to 9 ML under BC compared to 6 to 7 ML under CP. Maize yield was 19 t/ha with BC and 26 t/ha with CP. Timesaving was identified as an important benefit of system conversion with CP compared to BC. For example, the farmer discussed that they would travel 16 times to open and close the outlets of 16 bays using their BC system. While he could have installed automation to open and close the bay outlets to save time, this would be difficult to achieve given the undulating topography. 'The time I spent to spread fertiliser and chemicals under BC may be tenfold compared to CP' said the farmer. The farmer also identified saving 10% area using CP which was previously under channels, check banks and fences for the BC system and that weeds were less of a problem using the CP systems. Another benefit identified with the CP system was the volume of water used per day with BC using 15 to 20 ML per day flow while CP needs only a 2 to 7 ML flow rate depending on the number of spans and amount applied. This point became apparent when pumping from a dam or lagoon i.e. dams do not need to be as large for CP. The ease of operation and lifestyle was also identified as an advantage of the CP system.

Overall comments 'The CP machines are a lot easier to use and I have no other choice to irrigate the undulating land'. Before the purchase of CP machines, the farmer discussed with local suppliers and sourced their advice and quote from W&P Pumps who supplied and installed the CP system on his farm.

Farmer CP2

This is the same farmer who has also installed SD system (Farmer SD2) on his property.

Background The farmer has one CP machine with six spans and irrigates 36 ha of undulating land. There is no end gun on this CP. The CP machine is operated using a 37 KW electric motor. One rotation of the CP applies 5.5 ML water which means that water application rate is approximately

15 mm/day and the system is also used for fertigation. The farmer generally grows winter crops under CP such as sunflowers, radish and chickpeas.

Motivation When the farmer purchased the property, the area was undulating and irrigated by 100 small bays which were difficult to manage.

Cost of CP The farmer purchased the CP 18 years ago and at that time the cost of the machine was $100,000, which was $2,778/ha.

Maintenance of CP The farmer has spent $2,000 on maintenance over the past 18 years of operating the machine. The CP was serviced for the first time in 2019. The farmer identified that wheel rutting is a constant issue and he used sand and gravel to manage this. He has previously had to replace the gearbox of the machine which was damaged after a tyre had blown out due to rutting. Occasionally the pipes leak however the farmer identified that this was easy to fix. The farmer mentioned that it was difficult to fully replenish soil moisture on high spots of undulating land using the CP system.

Benefits of conversion The farmer discussed that CP systems have their place and are best for use with annual crops. He has saved 5 to 10% of land which was previously under channels, check banks and fences when using a BC system.

Overall comments The farmer believes that while CP systems have their place, in his experience, SD outperforms CP and PR systems.

Pipe and riser irrigation system (PR)

Farmer PR1

Background The property is a 400 hectares dairy farm in northern Victoria. The PR system covers 77 ha which has been converted from BC. This change has allowed the farmer to utilise the full delivery of water to his property of up to 20 ML/day. This water is sourced through a delivery outlet and is directed through a 1.5 km farm channel to a 7 ML farm drainage reuse dam. From the dam, the water is pumped through the PR system. The property has a mixture of Cobram sandy loam, Cobram loam and Moira loam. The Cobram loam is a relatively permeable, non-cracking soil profile while Moira loam had a permeable loam topsoil with a sudden texture change to a dense and impermeable clay at 20 cm depth that cracked when dry (Butler et al. 1942). The PR system grows 15.5 hectares of annual pasture and 61.5 hectares of perennial pasture.

Motivation The motivation for the farmer to convert their system to PR was on two levels: ease of operation and on-farm improvement. The desire for easier operation of the system was driven by the higher and more consistent flow rate: an improvement from 8 ML/day to 20 ML/day which has allowed the farmer to become confident in the use of his time-based automation system. On-farm improvements made include production gains, water savings, labour and vehicle savings as well as the associated lifestyle benefits. Since conversion, the bays can now be irrigated in any order resulting in overall better management of grazing rotations.

Cost of PR It cost $3,660 per hectare for the installation of PR which includes capital expenditure for improved on-farm infrastructure, laser grading and installation of the system. This cost also factors in the price of the pump station, power connection to the pump station and construction of the reuse system.

Maintenance cost Maintenance costs were identified as 2 per cent of the capital cost.

Benefits of conversion The farmer identified that following conversion his production of annual pasture increased from 2 t DM/ha/year to 5.5 t DM/ha/year and perennial pasture doubled from 6 t DM/ha/year to 12 t DM/ha/year. The farmer also reported a water saving benefit of 2.2 ML/ha following conversion of the irrigation system. Labour savings were also identified as a key benefit by the farmer and that this was one of the drivers behind the upgrade. The farmer commented: 'it was nearly a full-time job chasing water before the project'.

Overall comments The modernised irrigation supply system provides a more reliable water delivery service to the farm which increased the farmer's confidence to invest in farm irrigation infrastructure upgrades. A large and more consistent flow rate has also enabled faster irrigation and time-based automation to be used. The farmer identifies substantially shorter water ordering times which have enabled him to drive higher pasture growth rates by better matching water applications to plant requirements. "*Before the project, I'd get up in the morning and some bays were not done and other areas were swamped"* commented the farmer. The project enabled the farmer to install PR which provided tremendous benefits including convenience, flexibility and an improved lifestyle. To install PR, the farmer obtained information from Agriculture Victoria extension staff, the internet and local PR companies.

Farmer PR2

Background The property has predominantly Lemnos loam soil with some Goulburn loam, Congupna clay loam and Shepparton fine sandy loam. Goulburn loam is a dark brown loam to dark yellowish-brown clay loam with a change in texture at approximately 12 cm depth to medium clay, with relatively low permeability. Congupna clay loam is a grey to brownish grey clay loam with a change in texture at approximately 15 cm depth to medium heavy clay subsoil of low permeability (Skene and Poutsma 1962). The farm irrigation upgrade included: conversion of 11 ha of relatively high dryland area to perennial pasture serviced by PR which was previously difficult to irrigate using BC; 19 ha of perennial pasture previously serviced by nine inch clay pipes and small sliding door outlets and upgraded to improved BC; 15 ha annual pasture which was under PR and converted to perennial pasture; 25 ha perennial pasture which was irrigated by BC and converted to PR. Automation to open and close irrigation outlets remotely was also installed to all areas.

Motivation The farmer identified labour savings and lifestyle benefits as the key factors behind converting to PR.

Cost of PR The cost of installing PR was $5,290/ha. The cost of improving 19 ha of BC was $2,113/ha. For the PR system, the energy cost to pump water from on-farm storage dams is $10/ML (Maskey, 2014).

Maintenance cost The maintenance cost is approximately 2% of the capital cost. The farmer also pays a $700/year licence fee to an irrigation company to utilise their online irrigation automation system.

Benefits of conversion Pasture production increased from 4 t DM/ha to 12 DM/ha on the 11 ha previously dryland area. The production of perennial pasture under improved BC also increased from 10 t DM/ha to 11 t DM/ha. The production was increased from 6 to 11 t DM/ha by converting annual pasture to perennial pasture and the production was also increased from 10 to 12 t DM/ha on 25 ha which was converted to PR. The farmer identified that the water used had either remained the same or increased due to changed irrigation and land use.

Overall comments The farmer identified that he was happy with the improved irrigation system and that the new system was lot easier to use. The 'lifestyle' benefits achieved were one of the main factors behind the farmers decision to upgrade the system. To install PR, the farmer sought information from Agriculture Victoria extension staff, the internet and local PR companies.

Extension learnings

Understanding irrigators views and perceptions on why they decided to move away from traditional BC irrigation systems to the adoption of pressurised irrigation systems is critical. This understanding allows extension officers to customise extension programs that support other irrigators in the area to make similar complex decisions and achieve maximum benefit for their farm businesses. With increasing water prices, water savings have become an important driver of irrigation investment. All case study farmers have increased their water use efficiency and reported water savings made with the irrigation upgrades were substantial. The study shows that if water savings together with production gains can be realised, investing in such technologies can provide an attractive return on investment. The perceptions of these case study irrigators can be used by other irrigators considering similar options to evaluate the potential benefits however need to be validated with on-ground research findings to ensure the accuracy of their claims and whether the benefits can consistently be achieved.

Improved flow rates through delivery outlets and the reliability of water delivery to case study farms has resulted in larger areas being irrigated or the same area watered in less time. High consistent flow rates and automation of new irrigation systems has also resulted in labour and vehicle use savings for the case study irrigators. Farm field days could be held at these case study sites to provide broader opportunities for other local irrigators to view these new irrigation technologies on-farm and understand the works completed, which could provide an effective means of improving decision making capabilities for other irrigators considering such upgrades on their own properties.

This study to understand irrigators responses shows that adoption of new irrigation technology has a range of impacts on individuals depending on their farm context. Across the study area, farm context is highly variable. Many aspects need to be carefully considered by individuals before these decisions are made because of the important flow on impacts of these decisions on-farm. Irrigators will need to weigh up costs and benefits of adopting practices such as connection to the modernised delivery system and adoption of new irrigation technology as well as external influences such as seasonal water allocation and commodity price fluctuations. The complexity of decision making for irrigators to adopt new irrigation technologies requires a specialised approach from extension programs, which should provide relevant information and assistance to irrigators that meet their needs.

Table 1. Summary of the findings from farmers' interviews

Farm	Soil type	Capital cost ($/ha)	Perceived benefits	Perceived barriers
SD1	Lemnos loam, Shepparton fine sandy loam.	9,000	The farmer saved 25% of water and increased lucerne yield by 30%. Able to increase productive area by 5% which was previously under channels.	Water leakage from drip tapes and emitters is the major maintenance issue, which was more prominent during the first two years.
SD2	Shepparton fine sandy loam.	8,000	Water usage in SD was 6.0 ML/ha compared to 10.0 ML/ha under BC. Lucerne yield was 20 to 30% higher with SD. 5% increase in area which was previously under channels.	Power is the main ongoing operating cost. Farmer did not graze lucerne to avoid pugging.
CP1	Shepparton fine sandy loam.	3,000	Area of maize grown was 16 ha for BC and 16 ha after conversion to CP. Water usage reduced from 8.5 ML/ha with BC to 6.5 ML/ha with CP. The yield increased from 19 t DM/ha with BC to 26 t DM/ha with CP.	Power is the major operating cost.
CP2	Shepparton fine sandy loam.	2,780	Water and yield comparison were not available because when the farmer bought the land, he immediately converted the area into CP. Able to increase productive area by 5 to 10% which was previously under channels.	It is always difficult to replenish soil moisture on the higher areas of undulating land.
PR1	Cobram loam, Cobram sandy loam, Moira loam.	3,660	Production of annual pasture was increased from 2 t DM /ha to 5.5 t DM/ha and that of perennial pasture from 6 t DM/ha to 12 t DM/ha. Water saving was 2.2 ML/ha.	Ongoing operating cost is one of the barriers to adopt this system.
PR2	Lemnos loam, Goulburn loam, Congupna clay loam, Shepparton fine sandy loam.	5,290	Production of perennial pasture was increased from 10 t DM/ha to 12 t DM/ha on 25 ha which was converted to PR. The water usage either remained the same or increased due to change in land use.	Initial capital cost for the project was considered expensive.

Discussion

The results of this study show that the reasons for conversion to pressurised systems varied among farmers, however commonly included water and labour savings, ease of management and more efficient irrigation of undulating land and lighter soils. All farmers believed that they had saved water and increased yield with the conversion to pressurised systems. Technically, we do not know that this increase in yield was due to system conversion or other improvements made to farm management practices such as changes in fertiliser management, irrigation scheduling, pasture species and grazing management. With the dry seasonal conditions currently being experienced in the region and increasing water prices, water savings is also an important driver for investment in pressurised systems.

Despite these drivers, BC irrigation is still the major irrigation system used within northern Victoria to grow pasture. Farmers who want to convert to pressurised systems should consider the likely production gains which can be achieved by conversion along with their individual farm conditions, skill and ability to manage the new system. Farms which are less developed may potentially gain more in terms of productivity, water and labour saving than farms which have a well set up and managed BC irrigation system. Farmers may also need to update their skills to manage and ensure they gain the full benefits from installation of an upgraded irrigation system which can differ from more conventional systems such as BC. Some farmers noted that it could take one to two years to fully familiarise themselves with the operation and management of a new irrigation system. The farmer should also keep in mind that the cost of pumping is an extra cost in addition to the cost of water compared to gravity BC system.

The future of irrigation in northern Victoria depends on the ability of farmers to use limited water resources more efficiently. In this regard, the selection of an appropriate irrigation system is crucial. The information provided in this study can assist landowners and irrigation service providers in the selection of appropriate irrigation systems. It describes first-hand the information and experience of farmers and their experience of the benefits and barriers of adopting a new irrigation system. While this information may be most useful for the irrigation industry within northern Victoria, it may also be useful for other areas as well.

Conclusion

The results of these case studies show that all farmers identified they had saved water and increased production with the conversion to pressurised systems. However, part of the water savings and production gain may be due to improved farm management practices and upgrading the irrigation system. Labour savings were identified as substantial with pressurised systems. All farmers saved 5 to 10% in land area which was previously under farm channels. The farmers identified that energy cost is a major ongoing cost for pressurised systems. Individuals who want to convert to pressurised systems should assess their own situation and make sure that they can increase production and save water and labour to make their systems economically viable. Agriculture Victoria extension and research staff can provide impartial advice and information to irrigators so that they can make informed decision to adopt irrigation technologies that best meets their needs.

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