

Adoption of centre pivot irrigation in the irrigated dairy industry of south-eastern Australia

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Abstract. This paper reports on a study to answer the research question; why do dairy farmers adopt (or not adopt as the case may be) centre pivot irrigation (CPI) in the Central Goulburn Irrigation District (CGID) of southeastern Australia? Twenty-two dairy farmers were interviewed. Ten of these farmers had adopted CPI, four were considering adopting, and eight of the farmers were not planning to adopt CPI. The farmers interviewed represented the range of irrigated dairy farm sizes and production practices found within the CGID. The interviews were conducted and the data analysed as per the methods developed by Kaine (2004; 2008). We found that dairy farmers in the CGID only adopted CPI if their farm context (the farm's physical characteristics, the farmers' mix of skills and existing practices) meant that CPI would provide a relative advantage over alternative irrigation options. Therefore, CPI was only adopted when a farmer: required additional cattle feed; wanted to grow crops in a 'cut and carry' system to meet these requirements; and had access to undeveloped, physically suitable land. These findings suggest that rather than the adoption rates of CPI in the CGID being low, the market for CPI within the CGID is small. This is useful information that will enable realistic targets for adoption to be set, and guide research and extension in the CGID.

Keywords: adoption, centre pivot irrigation, irrigated dairy industry, Central Goulburn Irrigation District, southeastern Australia.

Introduction

The irrigated dairy industry in the Central Goulburn Irrigation District

The Shepparton Irrigation Region (SIR) has the highest concentration of dairy farms in southeastern Australia, with around 2,800 farmers (Linehan et al. 2004) producing 22.4% of Australia's milk in 2006/07 (Dairy Australia, 2008). The Central Goulburn Irrigation District (CGID) sits within this region and contains 814 of these dairy farms (Linehan and McAllister 2007, see Figure 1).

The people managing these farms are currently facing an unprecedented challenge with regard to irrigation water becoming increasingly expensive and scarce due to 11 consecutive years of dry conditions (BOM 2008) and increased demand from urban, recreational and environmental users (Victorian Government 2008). In 2008/09, dairy farmers in the SIR received 33% of their water allocation if they were on the Goulburn system or 35% if they were on the Murray system. Prior to 1995, these farmers received 200% of their water allocation (GMW 2009). Meanwhile irrigation water prices rose from $20 per megalitre (pre-1999) to an average of $365 per megalitre in the 2008/09 irrigation season (Waterfind 2009).

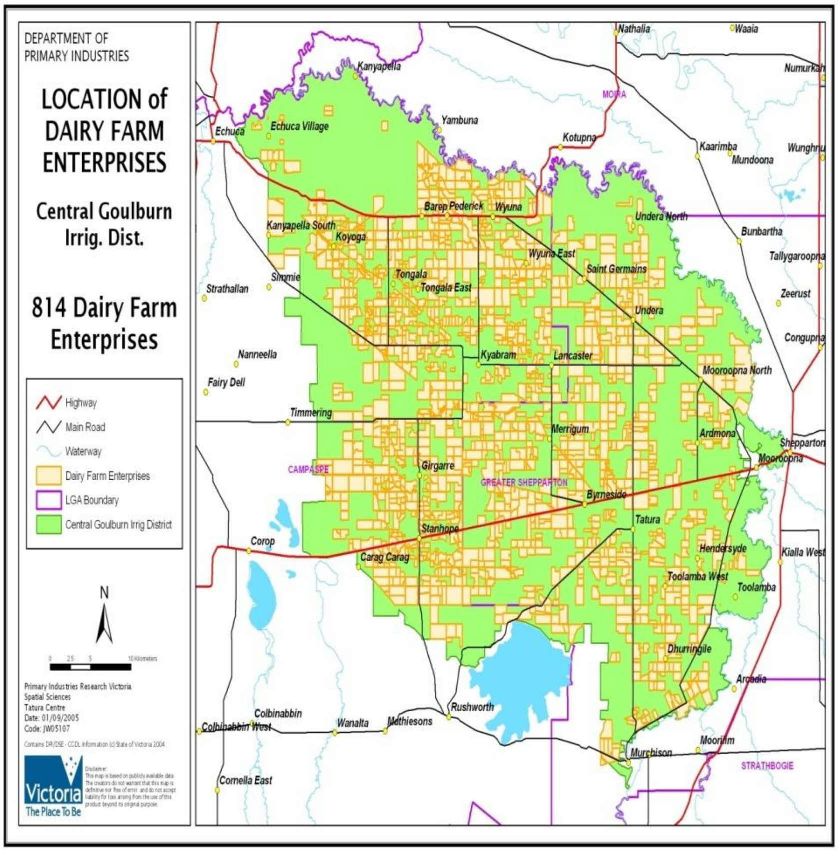
Centre pivot irrigation

Centre pivot irrigation (CPI) is a form of sprinkler irrigation consisting of several segments of pipe (usually galvanized steel or aluminium) joined together and supported by trusses mounted on wheeled towers with sprinklers positioned along its length. The system moves in a circular pattern and water is fed from the pivot point at the centre of the arc.

Research has demonstrated that CPI can reduce water use by 5%, while increasing the productivity of perennial pasture by 10%, compared to the traditional border-check, gravity flow irrigation (Qassim et al. 2008). Converting from border-check to CPI was found to be economically feasible in the CGID (Wood et al. 2007). Other studies have found that using CPI provided farmers with a greater ability to match irrigation applications to crop water demand, with improved nutrient management, increased management flexibility and reduced labour costs (Maskey et al. 2006; Qassim et al. 2008).

Despite these advantages, and investment by the Department of Primary Industries in an extensive program of research and extension, adoption of CPI was perceived to be low in the CGID (Maskey et al. 2006). Pomfret (2000) reported adoption of CPI at less than 10%, while Maskey et al. (2006) reported that less than 2.5% of the dairy farms in the CGID had adopted CPI. We did not find any published information on the level of adoption of CPI in other regions or industries.

Figure 1: Location of dairy farms in the Central Goulburn Irrigation District



Source: Linehan and McAllister (2007)

The benefits and barriers to adoption of CPI

Seeking to understand why adoption of CPI was low, Maskey et al. (2006) surveyed 20 dairy farmers in the CGID who had adopted CPI. They questioned the farmers about the benefits of, and barriers to adopting this irrigation system. The major benefits the farmers were seeking through their adoption of CPI were saving water through reduced runoff and saving labour as CPI is an automated system (Maskey et al. 2006). Foley and Raine (2001) found that cotton growers in Queensland sought the same benefits through their adoption of CPI. The barriers dairy farmers rated as most important were: the capital cost of the equipment, presence of trees, and the operating and maintenance costs of the system (Maskey et al. 2006).

An assumption that CPI could potentially be adopted on all irrigated dairy farms in the CGID underpinned the Maskey et al. (2006) study. Hence the benefits and barriers identified were the major factors influencing the adoption of CPI. If this assumption was correct, the adoption of CPI should be much higher as saving water and labour was, and continues to be, important to all dairy farmers in their efforts to reduce costs and increase productivity in order to remain financially viable (Bethune & Armstrong 2004). Yet only 2.5% of the dairy farmers in the CGID had adopted CPI. Therefore, the research question for this study was, Why did dairy farmers in the CGID adopt CPI?

Adoption research

Adoption research literature was referred to, but did not reveal a consistent approach to understanding the adoption of agricultural innovations, with different studies producing inconsistent, inconclusive or even mutually contradictory results (Feder et al. 1985; Knowler & Badshaw 2007; Kaine 2008). Kaine (2008) suggests that part of the reason for this confusion is that there are a number of theories as to why primary producers adopt agricultural innovations. Kaine (2008) illustrates this point by highlighting that the theory of technology transfer and diffusion of innovations emphasises the innovativeness of the producer, farming systems theory emphasises producer participation in the research process, and other theories emphasise learning and human development as the key determinants of adoption. In the adoption research literature there has also emerged an understanding of innovation as a socially and territorially embedded process (Koutsouris 2009), with adoption of innovations depending on a range of personal, social, cultural and economic factors as well as on characteristics of the innovation itself (Vanclay 2004; Pannell et al. 2006). Marra et al. (2001) described adoption as a function of the farm, the farmer and the characteristics of the innovation.

One thing most adoption researchers agree on is that the individual considering adoption must perceive that the innovation or technology will provide a 'relative advantage' or additional benefit above that provided by the individuals' current practice (Rogers 1995; Vanclay 2004; Pannell et al. 2006). From a farm systems perspective the benefits (and costs) of adopting a new technology such as CPI will depend on how the CPI integrates with certain technologies, practices and resources that are already in use on the farm (Kaine and Bewsell 2008).

The Kaine framework

Kaine (2004), Kaine and Bewsell (2008) suggest that the technologies, practices and resources present on a farm are part of its "farm context". The farm context also includes biophysical characteristics such as soil type and proximity to irrigation water, enterprise characteristics such as irrigation infrastructure and paddock size, human resources such as the availability and skill levels of available labour, and existing farm practices such as type of crop production or pasture management. These factors all combine to determine the cost, and potential benefits of adopting an innovation such as CPI. Kaine (2004; 2008) developed a framework to enable the key aspects of the farm context for a specific innovation to be identified, and hence to infer the likelihood of an innovation providing a relative advantage and potentially being adopted.

Farmers can then be sorted into market segments based on the presence of all, some or none of the key aspects on their farm. The creation of market segments enables the segments to be quantified (if required), the discrete needs of the farmers in each segment to be studied, and an opportunity to be provided to create targeted extension messages or products for the relevant segments (Kaine et al. 2005). Market segmentation has been used in agriculture before, however Kaine's approach is the unique in that the concepts of farm context and potential benefit to underpin the segments (Kaine et al. 2005), make it suitable to use when answering our research question: Why did dairy farmers in the CGID adopt (or not adopt) CPI?

A range of information is available on the theory underpinning Kaine's framework (Kaine 2004; 2008; Kaine et al. 2005; Bewsell et. al 2008), which has been widely used to study the adoption of a number of innovations in a range of industries. These include for example: soil moisture and automatic irrigation bay monitoring on dairy farms (Kaine and Bewsell 2002), soil moisture monitoring of pome and stone fruit (Kaine and Beswell 1999), sheep breeding and sire selection (Kaine et al. 2006) and soil management on livestock enterprises (Kaine and Niall 1999). Consequently, our study did not aim to develop or refine a new method, but rather to apply an established method to a new topic.

Methods

Twenty-two dairy farmers from the CGID were interviewed in order to identify the key issues influencing the adoption of CPI. Ten of these farmers had adopted CPI, four were considering adopting, and eight of the farmers were not planning to adopt CPI. The farmers were identified through industry and service provider contacts and represented the range of age groups, backgrounds, herd and farm sizes, and farm systems found in the CGID.

The interviews were conducted using a laddering process (Grunert and Grunert 1995). This process starts with the farmer being asked general questions about the subject of interest, with the questions becoming increasingly precise in response to the detail being provided by the interviewee (Kaine 2008). This technique enabled the systematic exploration of the reasoning underlying the decisions and actions of the interviewees. This in turn allowed the identification of similar and dissimilar patterns in reasoning among the interviewees, and the rationale for these patterns (Kaine 2008).

Interviewing farmers who had not adopted CPI helped with identification of the farm context and reasoning where adoption of CPI was not perceived to provide a benefit. Farmers considering adoption of CPI were interviewed seeking insights into the types of information and the key factors in the adoption decision-making process. The range of farmers interviewed, and use of this interviewing process allowed the elements that constitute the farm context to emerge through disclosure, testing and confirmation (Kaine 2008).

During the interviews, questions were asked about the farmers' access to irrigation water, farm size, labour management, herd number, and farming strategies regarding perennial pasture, fodder conservation and supplementary feeding of cattle. The sampling and interviewing process was considered complete when repeated interviews did not provide any new information and the interviewers were satisfied that they had logically consistent explanations for the patterns of reasoning and the decision making the farmers described (Kaine 2008). Two interviewers recorded interview responses manually and summarised and analysed them using case and cross-case analysis (Patton 1990).

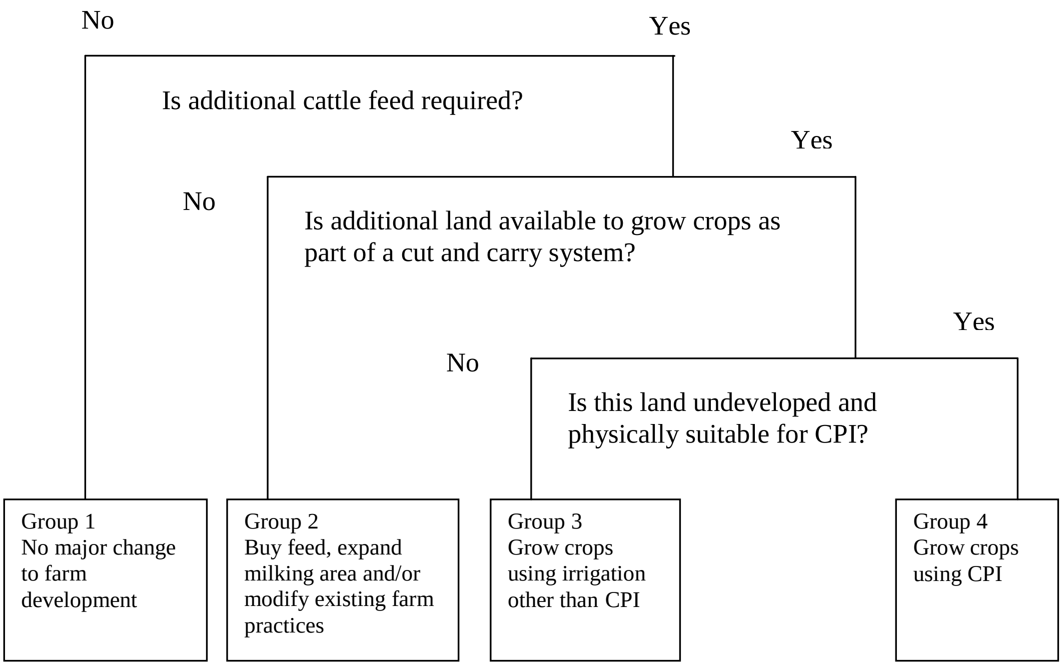
Results

The farmers who adopted CPI met each of the following criteria. They:

- required additional cattle feed
- wanted to grow crops in a cut and carry system to meet these additional feed requirements
- had access to undeveloped land, physically suitable for CPI.

All of the dairy farmers interviewed said that the medium- to long-term viability of their farm businesses depended on them increasing, or maintaining the productivity of their farms. They found this a challenge in the face of falling milk prices, dry seasons and rising input costs. The farmers were placed into four groups based on how they responded to these challenges (see Figure 2).

Figure 2: Decision tree of farm context leading to adoption of CPI



Group 1 - No major change to the farm

Two of the farmers interviewed were not changing their farms to meet this challenge as they were satisfied with their existing farm system, were close to retirement, or were planning to leave the industry. They had not, and were not planning to make any major changes to their farms and therefore were not considering adopting CPI.

All of the other farmers interviewed were increasing their farm productivity using a range of strategies, depending on a number of factors including available capital, farm size, labour and their existing farm infrastructure, machinery and management practices. All these strategies depended, to some extent, on increasing the number of dairy cows to produce additional milk. This led to a need for additional feed for the herd.

Group 2 - Buying feed, expanding the milking area, and/or modifying existing farm practices

Four of the farmers interviewed said they preferred to buy additional feed, often because they did not have more land, or capital available. For example, one farmer using this strategy told us:

> "I am expanding my herd, but I prefer to buy feed, rather than grow it. I can get hold of better quality feed that way, and someone else takes the risk of growing it".

Other farmers had decided to grow additional feed on farm. These farmers had access to additional land, either through purchasing or leasing developed blocks, or through developing "green sites" (previously undeveloped blocks). If the additional land was within 1 km of the dairy, the farmers had the option of extending their 'milking area', which is pasture for the cattle to graze on. If the land was more than 1 km away from the dairy, the farmers said it was too far to walk the cows there and back twice a day to milk them. None of these farmers adopted CPI because they did not perceive that growing perennial pasture under CPI was economically viable.

Jamie is a farmer using this strategy (names of farmers have been changed to protect anonymity). Jamie told us:

> "I am growing better and more grass to feed my cows. I have not invested in CPI as I don't see how growing pasture can justify the capital investment and operating costs".

Some farmers spoke about increasing the productivity of their existing land, or farms through changing pasture species, pasture management practices and/or aspects of their herd genetics or husbandry. Some of the farmers used two or all three of these approaches at the same time. These farmers suggested that these were incremental changes, limited by a number of dry seasons and lack of capital. This group of farmers were not considering adopting CPI.

Group 3 - Grow crops using irrigation other than CPI

Two of the farmers interviewed had obtained access to additional land, or were using part of their existing farm to produce additional feed as part of a cut and carry system. In a cut and carry system the farmer grows the fodder, harvests and stores it, and then feeds it to the cattle as required, using a feed pad or a feed pad/pasture combination.

If the existing or additional land was already developed none of the farmers interviewed said they were prepared to plough in an existing functional irrigation system to adopt CPI.

Mary explained to us:

> "I bought this farm eight years ago. It was laid out to flood (border-check) irrigation when I bought it, and I have relasered 25% of it since. There weren't many centre pivot irrigation systems around then. While I wouldn't mind doing things a bit more efficiently, I have spent the capital to laser grade so it would be a waste of money changing it".

Some of the farmers interviewed had thought about adopting CPI, but their land was not physically suitable. Carl is a farmer in this situation. Carl told us:

> "We were thinking about putting in a centre pivot but the paddock is on a spur channel so the water level fluctuates. We also have remnant vegetation, would have had to re-route the power line, and have only been able to irrigate ¾ of the circle. So we ended up putting the paddock under flood (border-check) irrigation".

Therefore, the farmers in this group were not considering adopting CPI, because either their land was not physically suitable, or because they did not perceive that CPI offered sufficient benefit over their existing practices to warrant the investment.

Group 4 – To grow crops using CPI

Ten of the farmers interviewed had adopted CPI when they were developing a physically suitable, previously undeveloped block to grow crops in a cut and carry system. A cut and carry system means that farmers grow, harvest then store and transport the feed to the cattle as required. While requiring specialized machinery, equipment, facilities and management practices, a cut and carry system enables farmers to utilize land that is too far from the dairy to be grazed, and reduces wastage as the cattle are not trampling and fouling pasture (Hodge and Hodge 2006).

The farmers that adopted CPI did so in order to grow crops and meet the feed requirements of their large or expanding dairy herd. They had a previously undeveloped block of land suitable for CPI (over 35 hectares in size, square or circular in shape, often undulating, with light soils and access to sufficient quantity and quality irrigation water, and without obstacles such as fences, power lines, trees, holes, dams or deep ditches in it).

Robert adopted CPI, he told us:

> "I spent $1,000,000 buying in feed during the first drought year, so I needed to increase our on-farm feed production. We had an undeveloped block that was

undulating, with fragile soils. CPI was the only option. I am growing annual crops under the CPI as this gives me the best nutritional value for my water".

The farmers that had adopted CPI said that the benefits of CPI above border-check irrigation were reduced labour requirements, increased productivity per megalitre of water and managerial flexibility. These farmers also said that purchasing a CPI was a large capital investment, however many believed they would have spent as much, or more money if they had tried laser grading their undulating block. Laser grading would also have damaged the soil structure, resulting in increased water runoff and erosion, particularly on light soils.

The other four farmers interviewed were still considering adopting CPI.

Discussion

CPI can increase productivity and reduce water use, yet there was a perception that adoption of CPI was low in the dairy industry of the CGID (Maskey et al. 2006). In this study, we found that even though the farmers mentioned the benefits and barriers to adoption of CPI described by Maskey et al. (2006), they were not the only factors that determined if CPI was adopted in the CGID. Dairy farmers in the CGID only adopted CPI if they: required additional cattle feed, wanted to grow crops in a 'cut and carry' system to meet these requirements and had access to undeveloped land that was physically suited to CPI.

A strength of the Kaine framework is that the aspects of farm context identified as key in determining if an innovation will provide a benefit though adoption, can usually then be used to quantify the market for that innovation. This would be more difficult to do with the more subtle or dynamic characteristics often used in other adoption research, such as farmer attitudes and goals or personal and social values for example.

After this study finished some of the biophysical characteristics identified (light soils, an area of undeveloped land, and access to irrigation water) were if fact used in conjunction with spatial data by Linehan and McAllister (2007) to see if they could quantify how many dairy farms in the CGID were suited to CPI. They identified fifty-three (6.5%) out of 814 farms which had these characteristics, which may provide a better estimate of the size of the potential market for CPI in the CGIR. However if we then consider the other factors identified as contributing to the adoption of CPI, for example if the farmers that owned these farms were not: considering making major on-farm changes (group 1), using cut and carry (group 2) or developing land (group 3), the number of potential adopters would most likely drop still further.

The adoption of micro-irrigation by fruit growers

The results of this study are similar in some ways to those found by Kaine and Bewsell (1999) who studied the adoption of micro-irrigation (pressurized) systems by fruit growers. The growers' properties had to have physically suitable soil types and access to irrigation water for micro-irrigation adoption to be possible. The fruit growers adopted micro-irrigation seeking to increase productivity through irrigating a greater number of trees, to optimize water use, reduce labor demands, and irrigate high density or trellis planted orchards. These findings are not surprising as the themes of needing to increase productivity and efficiency are reoccurring ones in the quest of the modern farmer to remain economically viable (Nossal and Gooday 2009).

Future research and extension

Consequently, research and extension work should be directed towards identifying and quantifying some of the agronomic options available to farmers. The more objective, reliable and relevant the information the farmer can access, the more chance the farmer has of making sound decisions about how to manage his/her unique farm system. We suggest that the potential use of CPI in non "cut and carry" farm system be explored in order to expand the current size of the market for this technology. If it was determined that the production of pasture was economically viable under CPI, then more of farmers managing the fifty-three farms suited to CPI (as identified by Linehan and McAllister 2007) may adopt.

In future smaller, cheaper CPI units may become available. While the farmers' criteria of wanting to grow additional feed on farm and having a area of land physically suitable will still be relevant, if the CPI is smaller more farms may have land physically suitable. Again, this would increase the size of the market for CPI.

Conclusion

CPI offers benefits in increasing farm productivity and reducing water use, yet there was a perception that adoption of CPI was low in the dairy industry of the CGID. In this study, we found that it was not only the benefits of and barriers to adoption of CPI described by Maskey et al. (2006) that determined if CPI was adopted in the CGID, but rather, that dairy farmers adopted CPI when developing a block of physically suitable land on which to grow crops in a cut and carry system, in order to feed a large or expanding dairy herd. A relatively low number of farmers and farms matched these criteria.

Traditionally lack of awareness about an innovation, unsatisfactory access to information or inadequate learning skills were often blamed for low rates of innovation adoption (Kaine 2005). This was not that case in relation to the adoption of CPI in the CGID. The low numbers of dairy farmers adopting CPI in the CGID does not represent a low rate of adoption, or that the extension program has failed. Instead the market for CPI is relatively small.

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