Irrigation Systems, Irrigation Management and Dairy Farming

First Report

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Executive Summary

There is a concern in the dairy industry that supplies of irrigation water may limit the growth of the industry in the future. There is also a desire in the industry to reduce the undesirable environmental effects of flood irrigation. Consequently, the effective use of water resources by dairy farmers is a key aspect of the industry's plan for achieving sustainable resource management and substantial resources have been invested to identify methods for increasing the efficiency of water use in the dairy industry. A range of improved practices for irrigating dairy farms have been developed in recent years. While some practices have been widely adopted others have not been so popular.

Our objective in this study is to identify and understand the factors that influence the adoption of irrigation practices on dairy farms in order to develop promotional strategies.

Interviews were conducted with researchers, extension professionals and dairy farmers from the northern irrigation region of Victoria to identify key irrigation practices and the factors influencing the adoption of those practices. The practices identified were laser grading of irrigation bays, automatic irrigation systems, recycling dams, spray irrigation, the use of groundwater for irrigation and scheduling irrigations using soil moisture monitoring.

We found, with the exception of spray irrigation on hilly or sandy country, that farmers were not adopting these practices to save water. The major factor in the adoption of laser grading (together with recycling systems), water babies and automatic irrigation was the benefits they offered in reducing the time farmers needed to devote to irrigation. Farmers irrigated with groundwater to augment limited or more expensive supplies of surface irrigation water. We found that farmers are unlikely to adopt soil moisture monitoring either because the available methods are no more accurate than their experience, or they are impractical to use because they cannot water on demand.

It follows from our findings that improvements in water use efficiency stem mainly from changes in water augmenting practices such as pasture, fertiliser, fodder production and supplementary feeding practices and not from changes in irrigation practice.

Dairy farmers are not compelled to reduce water use because it appears water is not a key factor limiting production on most farms. If reducing water use to reduce the environmental effects of irrigation is a major industry and social objective then farmers access to irrigation water must be restricted.

If increasing water use efficiency to increase production is a major industry and social objective then policy and extension efforts should be directed toward encouraging the development and adoption of water augmenting practices. However, increasing water use efficiency does not necessarily lead to reduced water use and therefore does not necessarily reduce the environment effects of irrigation.

Acknowledgments

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We are indebted to the dairy farmers who participated in the study by being kind enough to grant us interviews.

All errors and omissions remain the responsibility of the authors.

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Introduction

There is a concern in the dairy industry that supplies of irrigation water may limit the growth of the industry in the future. There is also a desire in the industry to reduce the undesirable environmental effects of flood irrigation. As a result, the effective use of water resources by dairy farmers is a key aspect of the industry's plan for achieving sustainable resource management (Dairy Research and Development Corporation 1997; Mason and Craven 1997; Murray Dairy 1998). Consequently, substantial resources have been invested to identify methods for increasing the efficiency of water use in the dairy industry.

A range of improved practices for irrigating dairy farms have been developed in recent years. These include the laser grading of irrigation bays, the installation of automatic irrigation systems, the installation of recycling dams, spray irrigation, and scheduling irrigations using soil moisture monitoring. Some practices, such as laser grading, have been widely adopted (Douglass, Poulton et al. 1998). Other practices, such as automatic irrigation, have not been as popular (Douglass, Poulton et al. 1998).

Our objective in this study is to identify and understand the factors that influence the adoption of irrigation practices on dairy farms in order to develop promotional strategies.

We begin by drawing on consumer behaviour theory to characterise the decision to adopt a new farm practice as a form of complex decision making.

Adoption and involvement

The effort consumers invest in making decisions to purchase (or adopt) products, and the type of processes they follow in making those decisions, depends on how important the product is to them.

Low involvement purchasing occurs with products that are unimportant to the purchaser (Assael 1998). Usually, low involvement products are inexpensive and bought frequently. Many household goods such as groceries, laundry products and basic toiletries are low involvement products. The purchase process is characterised by passive learning and product evaluation after purchase. Generally, people spend as little time and effort as possible on purchasing low involvement products.

High involvement purchasing occurs with products that are important to the purchaser. Usually, such products are expensive, bought infrequently, are risky or are highly expressive of self-identity (Assael 1998). Homes, cars, and clothes are often high involvement products. The purchase process is characterised by active learning and products are evaluated prior to purchase. Generally, people invest a great deal of time and effort in purchasing high involvement products.

The adoption of a new farming practice is, usually, a highly involving issue for farmers and decisions about adopting a new practice tend to have the characteristics of high involvement purchases. Most innovative practices are likely to have substantial impacts on farmers' incomes and, in many instances, their lifestyle. The integration of a new practice into an existing farming system generally requires devoting considerable effort to planning and managing change.

This view of the adoption of new practices as a form of high involvement purchasing has a number of implications. First, it implies that farmers are likely to devote a substantial amount of time and energy to evaluating new practices they see as offering a potential benefit. Sometimes the adoption process can extend over several years (Kaine and Niall 1999). Second, this view implies farmers are unlikely to retain apparently outdated or inefficient practices simply on the grounds of tradition or conservatism. Third, this view implies that the decision not to adopt a new practice will be founded on a reasoned argument. Consequently, attempts to promote adoption that do not address such arguments are unlikely to meet with success.

This view of the adoption as a form of high involvement purchasing treats all farmers as potential innovators. This potential is given expression when a farmer is prompted by the discovery of a need to actively seek information about new practices to satisfy that need.

Adoption and context

Consumers purchase products to satisfy needs. Since the needs of consumers vary, one product usually will not meet the needs of all consumers. Consequently, products with different characteristics are required to satisfy the needs of different consumers.

Differences in consumers' needs arise for a variety of reasons, one of the most important being the usage situation or context in which the product is consumed (Assael 1998). For example, the uses for paper towels have been classified into heavy duty (cleaning ovens, washing windows and cars), light duty (wiping hands, counters and dishes) and decorative (placemats, napkins). Clearly, paper towels with different characteristics are needed for each of these situations. Consequently, consumers will employ different criteria to choose between brands of towels depending on the usage situation they are purchasing for.

Differences in farmers' needs also arise for a variety of reasons, again one of the most important being the usage situation. In the case of farming, the usage situation is defined by the farming context. This is the mix of practices and resources used on the farm that influence the benefits and costs of adopting the innovation (Kaine and Lees 1994).

(Rogers and Shoemaker 1971) identified five factors that influence the rate of adoption of innovations. These were:

- Relative advantage, which is the degree to which a new product is perceived to be superior to existing substitutes.
- Compatibility, which is the degree to which a new product is consistent with needs, attitudes and past experience.
- Simplicity, which is the ease with which a new product can be understood and used.
- Observability, which is the ease with which a new product can be seen.
- Trialability, which is the degree to which a new product can be tested or sampled before adoption.

In terms of the adoption of agricultural innovations, relative advantage and compatibility are usually strongly related since the benefits of adopting a new practice depend heavily on the ease with which it can be integrated into the existing mix of practices and techniques used in the farm enterprise. In effect, the resources and mix of practices and techniques used in a farm enterprise, the farm context, describe the farming equivalent of the consumers' usage situation.

Extension and market segmentation

One objective in market segmentation is to classify consumers into groups or segments based on differences in their needs. Such segmentation can be used:

- To determine the numbers of consumers in a segment;
- To infer the attributes of products that will best meet the needs of consumers in a particular segment;
- To identify the characteristics that differentiate consumers in one segment from another; and
- To formulate a strategy for marketing a product to a particular segment.

When the usage situation is the critical determinant of consumers' needs, then market segmentation should be undertaken using those variables that define key differences in usage situations. The role that segmentation can play in guiding the development of extension programs becomes clear given that the relative advantage and compatibility of agricultural innovations are largely determined by the usage situation as defined by the farm context. Consequently, different market segments for an agricultural practice can be described by identifying key differences in usage situations, that is, key differences in production contexts (see Kaine and Lees 1994; Kaine, Lees et al. 1994; Kaine and Niall 1999).

Having identified different market segments and characterised the usage situations peculiar to each it should be possible:

- To assess the goodness of fit between the needs of a segment and the characteristics of the innovation and use this information to formulate priorities with respect to targeting segments and to forecast the long term rate of adoption across segments;
- To draw inferences regarding modifications/adaptations to the innovation to better meet the needs of segments;
- To formulate extension programs that 'position' the innovation appropriately in terms of promotion themes and messages and, possibly, communication channels.

Understanding the adoption of irrigation practices in the dairy industry involves the following. First, identifying the technologies, current practices and resources at the farm level that influence the benefits and costs of adopting these practices. This involves interviews with farmers, extension staff and other relevant experts or specialists. Second, classifying dairy farmers into market segments based on key differences in their endowment of these technologies, practices and resources.

We interview extension staff and other specialists because they see new technologies in a number of contexts and tend to have a good feel for the factors that influence adoption. However, extension staff and specialists often have little contact with non-adopters. We also interview farmers who have successfully adopted the practice of interest. These farmers can offer excellent insights into factors favouring adoption and problems that can be experienced along the way. However, these farmers generally do not know why other farmers have decided not to adopt a practice. Consequently, we also interview farmers who have not adopted the technology of interest. Usually we get to meet with some farmers who have tried the technology but found it unsatisfactory. These people offer insights into the factors that prevent adoption.

The irrigation practices identified by farmers, extension staff and researchers to be investigated in this study were:

- Laser grading of irrigation bays
- Installation of recycling dams
- Monitoring irrigations using water babies
- Installation of automatic irrigation
- Installation of spray irrigation
- Installation of groundwater pumps
- Soil moisture monitoring

Each of these practices was discussed in our interviews with dairy farmers, irrigation researchers and extension staff. The results that emerged from these discussions follow.

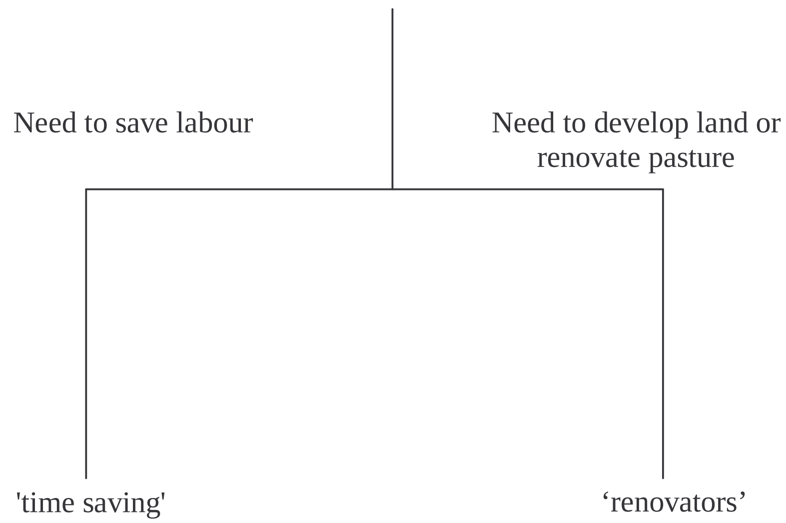
Irrigation practices in dairying

Laser grading of irrigation bays

This practice is widespread in among dairy farmers. Dairy farmers mainly undertake laser grading of irrigation bays to save time and labour. Most dairy farms were originally designed with numerous narrow, short bays and small bore water outlets. Irrigation on these farms was a time consuming task. This design has become increasingly impractical over time with increases in farm size and cow numbers.

A large number of narrow, short bays can be consolidated into a few long, wide bays by laser grading. Together with the installation of large bore water outlets and a corresponding enlargement of the internal system of channels on the farm, laser grading can dramatically reduce the amount of time spent checking water when irrigating the farm. David and Louisa are an example of these 'time saving' laser graders:

Figure 1 Context segments for laser grading



David and Louisa are sharefarmers on a100 hectare dairy property. Twenty hectares of the property were laser graded twelve or more years ago when lasering first came in. These paddocks are very flat but irrigate all right because the water is pumped. The rest of the farm has been graded by lasering 10 to 12 hectares every year. Lasering has reduced the amount of times David needs to go down the paddock to check the water as there are fewer bays.

There can be some increase in milk production from newly graded bays because of improvements in pasture composition and pasture growth. However, this increase may be off-set by production losses incurred over the five years it takes for a newly graded bay take to reach full production. For instance,

Ray and Heather run a dairy farm at Katunga. They have 120 hectares under irrigation. Ray has had 70 hectares of the irrigated area lasered. Finances are preventing him from lasering the rest at present. He lasered "to keep his sanity". One area that he has redeveloped originally had 45 to 50 bays with four inch outlets. Now the same area has three bays with 12 inch outlets. Lasering has dramatically decreased the time Ray spends checking water.

Lasered ground takes five years to come back into full production but on newly lasered paddocks Ray finds he gets a 10 per cent increase in milk production. "The cows perform better on it." So although redeveloping means that he has to lock up newly lasered blocks in winter to prevent pugging he is getting plenty of spring and summer growth to compensate.

It may be that some farmers, who are not under pressure to reduce the time they spend irrigating, may undertake laser grading of irrigation bays as part of a program of farm development and pasture renovation. Jamie is an example of a 'renovator' laser grader.

Jamie milks 245 cows on a dairy farm at Zeerust. Jamie has four wheels and two pumps that allow him to irrigate the property in shifts keeping one area dry for the cows. Each bay would be irrigated every seven days but because the irrigation is staggered the water is going every day during the summer.

Jamie has laser graded his whole property. He originally began the laser grading because some of the land was uncommandable (ie could not be irrigated).

Farmers who are not under pressure to reduce the time they spend irrigating and do not need to develop their land are unlikely to adopt laser grading. If the farm is manageable under the current layout and pasture production is satisfactory there is little incentive to undertake laser grading of irrigation bays as part of a program of pasture redevelopment and renovation. Note that laser grading can be impractical in relatively hilly or sandy areas.

Installation of recycling dams

Dairy farmers may install a recycling dam (reuse dam or turkey nest) for a number of reasons. First, farmers on channel systems subject to variable flow rates and delivery delays may install dams to increase their control over the timing and rate of application of irrigation water. This control also reduces the amount of time that farmers in these circumstances must devote to monitoring irrigations. Colin and Alan installed a recycling dam to store groundwater so that they could exert greater control over the timing of their irrigations.

> *Colin and Alan manage a large dairy farm near Kyabram. The farm is in two blocks milking 520 cows. Their "whole system is pasture based". Colin believes that good pasture growth comes from quick irrigation and good management. The home block was lasered 17 years ago. At the same time a turkey nest was built and automatic irrigation was installed. The other block was developed once the system proved itself. Their property is set up so bays can be irrigated in three to four hours. They use the turkey nest dams they have built to capture run-off and store groundwater. This gives them ready access to a reliable source of water.*

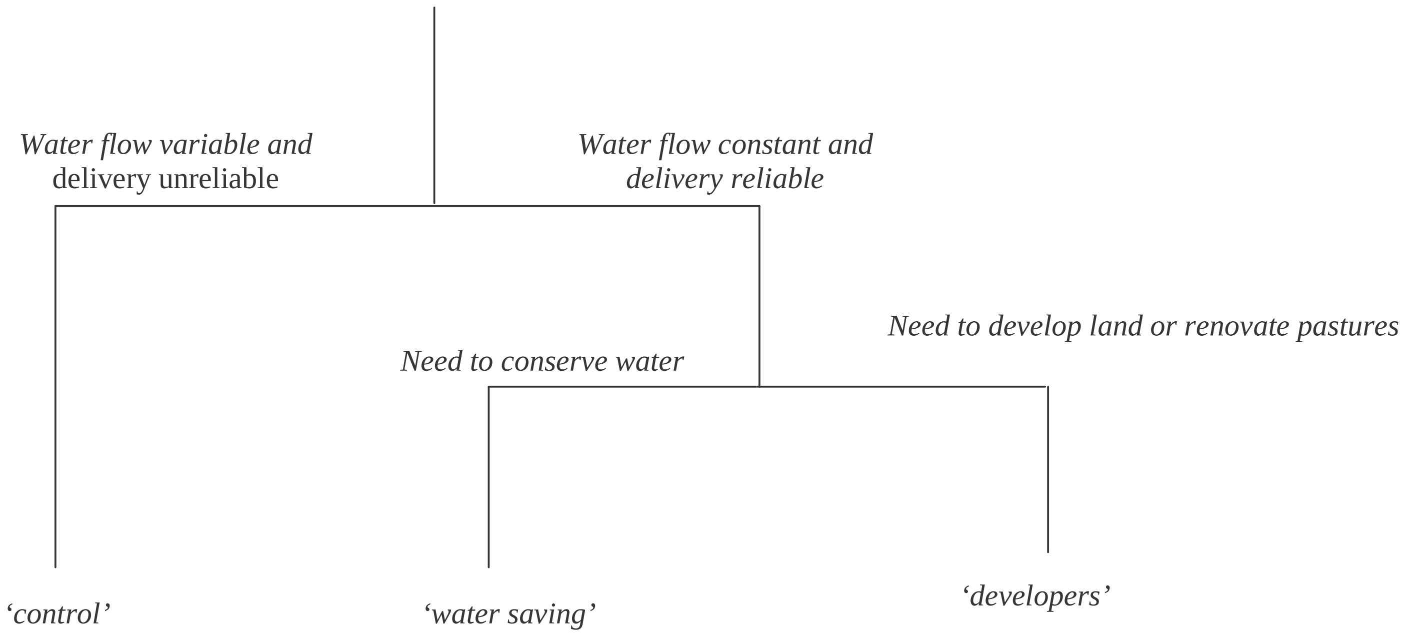
Alternatively, control over irrigation can be improved by using a recycling dam to store ordered water.

> *Kevin and Denise have a dairy farm in Tallygaroopna. Sixty percent of the property is lasered with a recycling dam. Although the remainder of the property waters "OK" they would laser it too if they had the money. Kevin does all the irrigating and milking by himself. Generally three days a week would be spent irrigating – more when he is irrigating the sub-clover. Kevin orders extra water when he irrigates and stores it as run-off in the reuse dam. He can then irrigate some paddocks on demand without having to wait for his ordered water to arrive.*

A second reason farmers may install a recycling dam is to conserve irrigation run-off or to store groundwater to augment limited volumes of irrigation water. For example,

> *Sandy runs a very large dairy farm near Wyuna. The farm was originally two separate properties but Sandy now manages both properties with the assistance of a number of staff. Presently he is only*

Figure 2 Context segments for recycling dams



growing perennial pasture, although normally he grows a mixture of crops.

Sandy irrigates once every seven days. This works in well with his fourteen-day pasture rotation. Integrating irrigation with stock rotation is a major issue for Sandy. He finds it difficult to be flexible with three herds to rotate. Sandy manages most of the irrigation scheduling, although he has one worker to manage day to day watering jobs.

Given the farm covers such a large area, even a small amount of run-off amounts to a pretty substantial amount of water. By recycling run-off through the reuse system Sandy can relieve some of the pressure on his water allocations.

Third, many farmers who invest in recycling dams probably need to install them as part of their property development plan when laser grading their irrigation bays. This occurs for a number of reasons. First, in many instances on-farm channels need to be enlarged to carry the larger volumes of water needed to irrigate lasered bays. Enlarging channels requires additional soil and this can be obtained by excavating a recycling dam. Second, there is a risk that large volumes of water may be lost if a lasered bay is watered for too long because of the high rate of water flow across lasered bays. The installation of a recycling dam counters this risk. For example,

Sally and Matt run a dairy just out of Numurkah. Their farm covers 55 hectares, 14 of which is sub clover. Two thirds of the farm is lasered which means those bays are bigger and have larger outlets. They have a recycling system that was put in when the laser grading was done. They used the dirt from the turkey nest to build up lanes and channels. The reuse system means that if one bay is watered for a bit too long they are able to capture and recycling that water.

Recycling dams are impractical in some situations because of unsuitable soil types or topography. For instance,

Sam owns a dairy farm just out of Leitchville. Over the years Sam has gradually built up his holdings of land and his herd from around 120 cows to 510 cows. All 180 hectares of the farm is lasered and about 30 per cent is under automatic irrigation.

Sam does not have a reuse system now. After putting in a reuse dam on the home farm he discovered that it was turning bays salty. This led to work on suitable soil types for reuse systems. The major soil type on Sam's property is a sandy loam and this was found to be unsuitable for reuse systems in his area because it allows salty groundwater to seep into them.

Monitoring irrigations using water babies

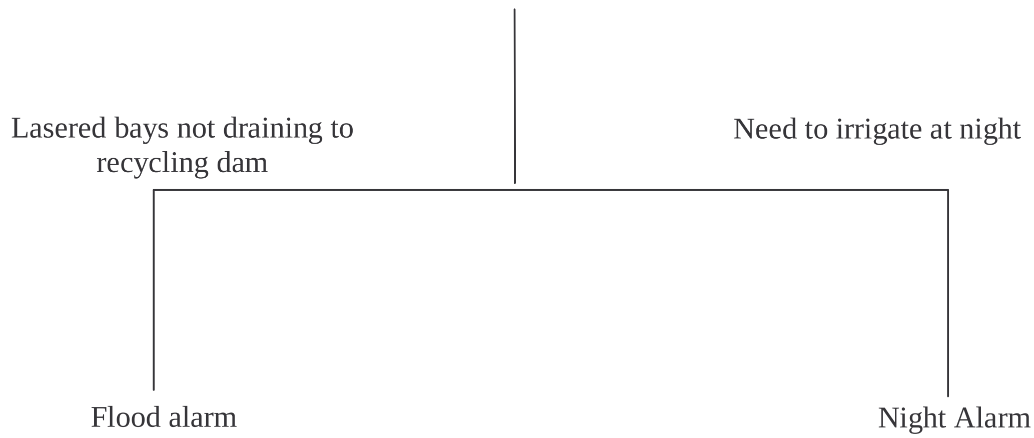
Farmers employ water babies to check or monitor irrigations when the task of monitoring is unusually demanding. Water babies are sensors or monitors that are placed in the bay at the point where the water should be shut off. When the water reaches the sensor it transmits a signal to a receiver which alerts the farmer. Water babies are helpful in situations when irrigations must be checked at times that are particularly inconvenient for the farmer, or when extra care is required to avoid the risk of major water loss. Checking irrigations can be a particularly inconvenient and irksome task when it is regularly required late at night. For example,

> *Graeme runs an 80 hectare dairy farm at Cobram. He is able to juggle the watering and milking as he has a worker to help in the shed. Graeme has lasered his entire property.*
>
> *Graeme uses a water baby on most of his bays. Graeme has to regularly get up during the night to check his water because of delays in the arrival of water he has ordered. He knows the bays have to be irrigated but he was sick of chasing water 'in the middle of the night'. Graeme believed the cost of fully automating the system was too high and he could "use the money for other things". Instead, he has used a water baby for the last four or five years. If the water baby alarm goes off it only takes ten minutes to go down the paddock and swap the bays over.*

Extra care must be taken with monitoring when small delays in closing off bays creates the risk of major water loss. On lasered properties there is a risk that large volumes of water may be lost if a lasered bay is watered for too long because of the high rate of water flow onto lasered bays. Typically, lasered bays are designed to drain into recycling dams to counter this risk. However, on some farms the topography or layout of the property may make it impractical to design all bays so they drain into a recycling dam. Farmers in these circumstances may use a water baby to avoid having to spend too much time checking on those bays that do not drain to a recycling dam. For instance,

> *Max owns a 140 hectare dairy farm made up of three separate blocks near Stanhope. Max has lasered his entire property but because he is on sloping country it was impossible to drain all the bays to a reuse dam. Because Max has to travel between the three blocks he cannot afford to spend too much time waiting for bays to 'come in'. Max has used a water baby for a number of years. He knows when the water baby alarm goes off he can go straight down and swap the bays over.*

Figure 3 Context segments for water babies



Installation of automatic irrigation

The major benefits of automated irrigation systems are savings in time and effort devoted to irrigation (Maskey 1996; Maskey 1998). However, as automatic irrigation equipment is expensive to install, most dairy farmers are unlikely to adopt automation unless their time is extremely limited. Also, farmers cannot usually install an automated system until the area to be irrigated has been laser graded which itself reduces the time required to irrigate. For example,

> *Jason runs a large dairy farm near Cobram. Most of his 120 hectare farm has been laser graded and he is intending to laser the remainder over the next year. He has a reuse system to catch rainwater and irrigation run-off and to store groundwater.*
>
> *Jason uses automated irrigation technology. Sensors have been installed in each bay that trigger a rubber flap at the outlet to stop the water and turn the next bay on. He installed the system primarily to remove error and to give him more social time. He now "enjoys watering a lot". He prefers this system to a computerised system that tended to make errors and was not as user friendly. With his mechanically based system Jason has to walk along the channel to set the triggers on the flaps so he can check for leaks, weeds and any other problems.*

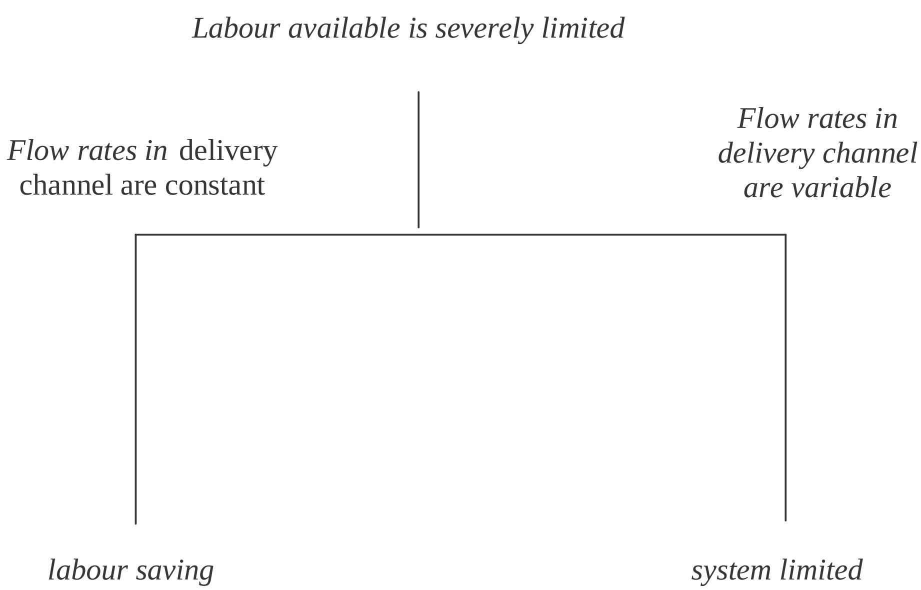
Similarly,

> *Vic has a 100 hectare dairy farm in East Shepparton milking 360 cows.* The *property is on a secondary district supply channel. The entire property is lasered, except for a small part of a recently bought block. Vic invested in laser grading as a way of reducing labour requirements. Vic installed an automatic irrigation system in 1983 because 'the laser guys said I could lay out the property for automatic irrigation and I thought why not so I went from there'. Installing automatic irrigation saved more time. He has tried several systems and has found a timer system is the most reliable and requires little maintenance.*

Farmers may be prevented from installing an automatic system if flow rates in delivery channels are unpredictable. This obstacle may be overcome by installing a recycling dam. For instance,

> *As described earlier Colin and Alan manage a dairy farm near Kyabram. The 300 hectare farm is in two blocks. Automatic irrigation was installed on the home block 17 years ago when it was lasered. To ensure reliable access to water they also invested in a turkey nest dam at the same time. The other block was developed along similar lines once the system proved itself.*

Figure 4 Context segments for automatic irrigation



> *Automatic irrigation has made managing such a large farm easier, especially as the other block is at some distance from the home block.*

Installation of spray irrigation

Dairy farmers are most likely to install spray irrigation on land that is unsuited to flood irrigation. Land may be unsuited to flood irrigation because the topography is hilly or the soil type is sandy. It does not appear that spray irrigation systems are less time consuming to manage than flood irrigation systems. For example,

> *As described earlier Jason runs a large dairy farm near Cobram. Most of his 120 hectare farm has been laser graded and converted to automatic irrigation. He has a reuse system to catch rainwater and irrigation run-off and to store groundwater.*
>
> *Jason has several blocks under knocker sprinklers that were installed when his grandfather first bought the farm. These have not been very successful as the cows rub against them, bending and breaking them, and chewing on them. Eventually the only sprinklers Jason will have will be on hilly ground that would otherwise be uncommandable.*

Installation of groundwater irrigation

A number of dairy farmers have installed groundwater pumping systems. The salinity level of the groundwater extracted will determine the uses the water can be put to. The main reasons for installing a groundwater pump are to augment surface water allocations or to increase control over the timing of irrigations. For instance, Sally and Chris invested in laser grading and groundwater pumping to increase the control they have over their irrigation.

> *Sally and Chris run a dairy with 110 cows just out of Numurkah. Originally, much of the farm was quite difficult to water – there were quite a few "really bad watering paddocks." Two thirds of the farm is now lasered which means those bays are bigger and have larger outlets. Chris has replaced a lot of the smaller outlets on the rest of the farm so that most bays water quite quickly. "I've made some five hour paddocks, four hours."*
>
> *Recently, Sally and Chris also installed a spear system installed. The water from the spears is shandied and used along with the channel water. With lasering, installing bigger outlets and using ground water and channel water Chris can now irrigate two thirds of the farm in only 23*

Figure 5 Context segments for spray irrigation

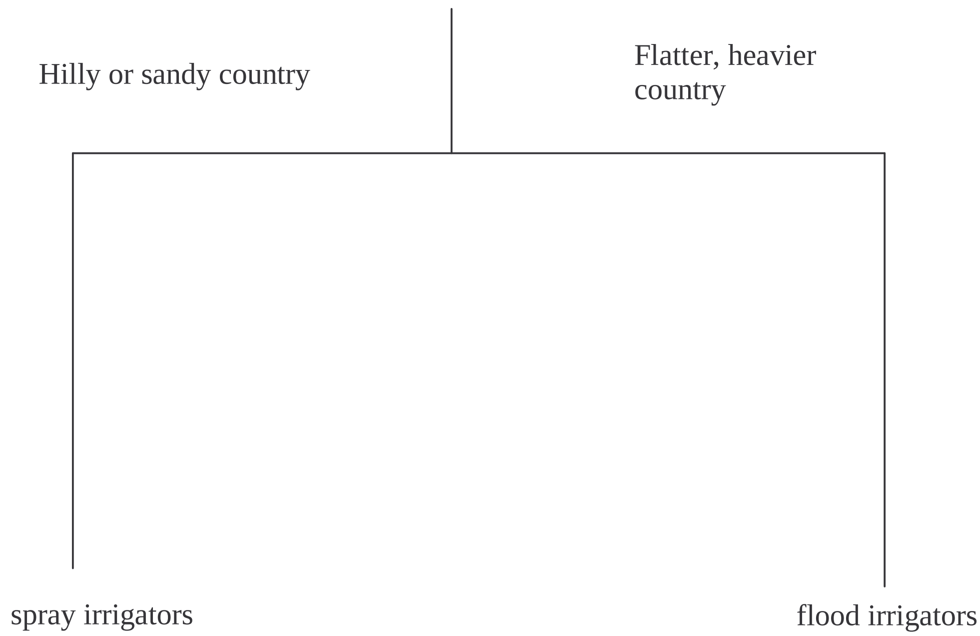
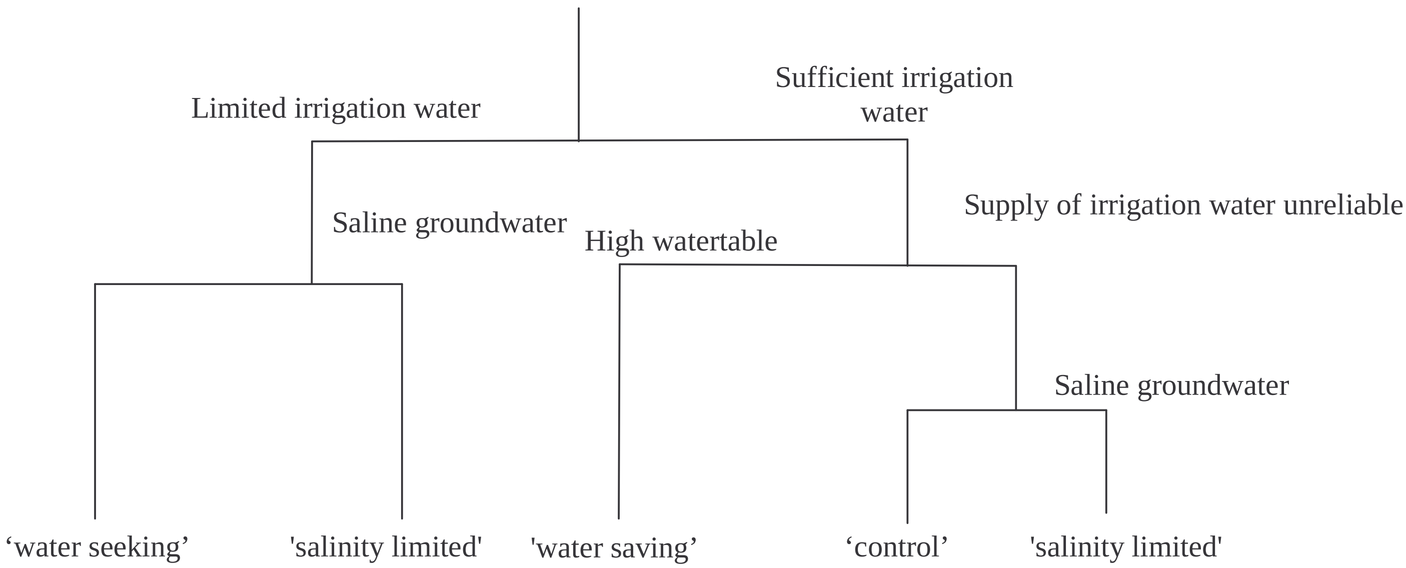


Figure 6 Context segments for groundwater irrigation



hours. He leaves one third dry so that the cows have dry paddocks to go into.

Jamie, in contrast, is investing in groundwater to boost his supply of irrigation water.

As described earlier Jamie milks on a dairy farm at Zeerust. His whole property has been laser graded. Jamie has four wheels and two pumps that allow him to irrigate the property in shifts keeping one area dry for the cows. Each bay would be irrigated every seven days but because the irrigation is staggered the water is going every day during the summer. Jamie is planning to put in a groundwater pump as he has a suitable site but this is a medium term plan because of the cost, which is expected to be approximately $80,000. Jamie has no salinity or groundwater problem so he will use the groundwater as an additional source of irrigation water.

Generally water from pumps can be used on farm either directly or after being 'shandied' by mixing with channel water to reduce the salinity. For instance,

As described earlier, Max owns a 140 hectare dairy farm made up of three separate blocks near Stanhope. Max has lasered his entire property but because he is on sloping country it was impossible to drain all the bays to a reuse dam. Max has three groundwater pumps. However he only uses one pump to irrigate with as the other two are too saline to shandy.

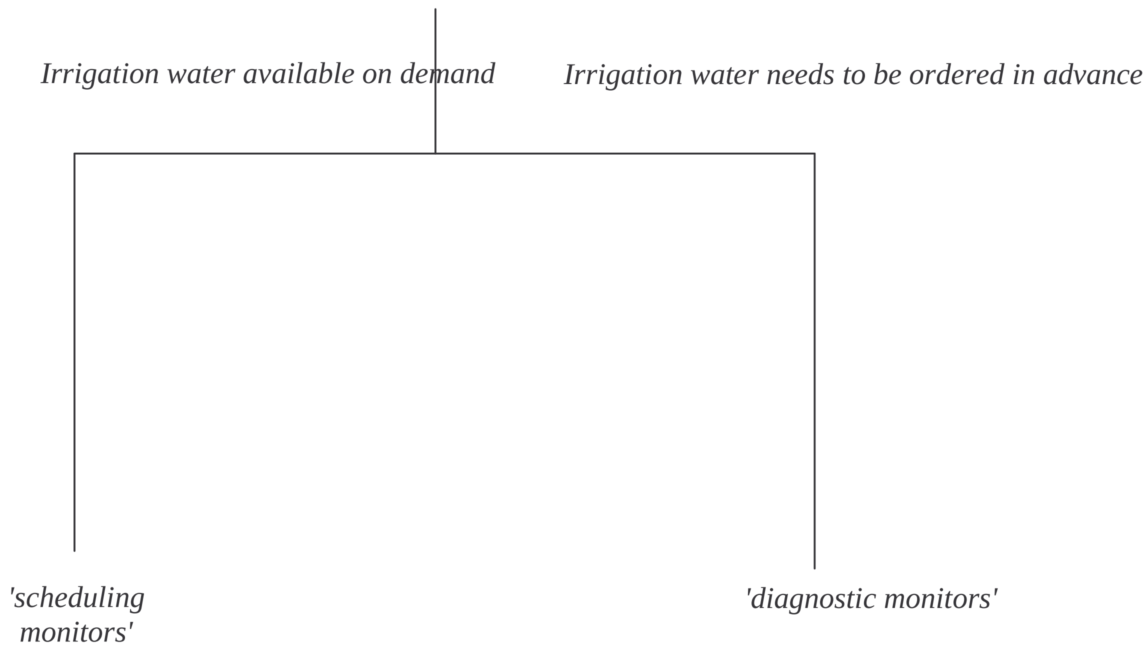
Another reason a farmer may invest in groundwater pumps is to alleviate a problem with a high watertable. We have not interviewed anyone in this situation.

Soil moisture monitoring

Few farmers, if any, appear interested in quantitative monitoring of soil moisture. Monitoring would be most useful at the start of the irrigation season during the spring when pastures are most susceptible to moisture stress because the growth rates are high. However, the forward ordering policy for irrigation water, and the need to irrigate within the constraints imposed by rotational grazing, mean that farmers do not have the managerial discretion to take advantage of more precise information on soil moisture conditions. For example,

As described before, Sam owns a dairy farm just out of Leitchville. All 180 hectares of the farm is lasered and about 30 per cent is under automatic irrigation.

Figure 7 Context segments for soil moisture monitoring



> *When Sam took over the farm from his father he looked at different ways of managing irrigation. He used evaporation data for a while but found that his experience matched the evaporation figures. He then tried using tensiometers. "Unless we had water on demand [instead of having to order water in advance] they proved to be useless." Sam also tried a neutron probe but this provided "little benefit" as he could already predict how wet or dry the bays were. "It was too expensive for just growing grass."*

Farmers with access to water on demand, such as those with recycling dams or groundwater, might employ monitoring to time irrigations more precisely.

Monitoring might be employed to assist farmers to decide when to conclude the irrigation season in autumn. However, given the relative insensitivity of pasture growth to soil moisture conditions during this period it appears there is little to gain from more precise measures of soil moisture.

It may be that farmers who are experiencing problems with pasture growth may install monitors to assist them in solving their pasture problem.

Water use and water use efficiency

In our introduction we noted that policy makers are directing substantial resources to promoting greater efficiency of water use in the dairy industry (Dairy Research and Development Corporation 1997; Mason and Craven 1997; Murray Dairy 1998). Increasing water use efficiency is desirable from an industry perspective and a community perspective. From an industry perspective increasing the efficiency of water use enables the industry to expand production even though the supply of irrigation water is fixed. From a community perspective increasing the efficiency of water use contributes to the sustainability of dairy production by reducing the undesirable environmental effects of dairy farming. Studies have shown there is a fourfold variation in water use efficiency across irrigated dairy farms in northern Victoria (see Armstrong, Knee et al. 1998).

Broadly speaking, there are two different approaches to increasing the efficiency of water use. One approach is to maintain production but to use less water. This means substituting other inputs for water. This approach involves adopting technologies and practices that are primarily *water saving*. Two important conditions must be met if the water saving approach to improving efficiency is to be successful.

One condition is the availability of appropriate techniques and practices. Broadly speaking, with the exception of spray irrigation on hilly or sandy country, none of the irrigation technologies or practices we have examined appears to offer substantial and widespread water savings (see Wood and Martin 2000). There may be some savings in water use associated with laser grading but these appear to be limited. Water babies and recycling dams provide safety mechanisms for preventing losses when delays occur in closing off irrigation bays. Automatic irrigation systems do not appear to have generated major water savings for those farmers that have such systems. Soil moisture monitoring seems to be either impractical or to offer only trivial savings in those cases where it might be practical (see Bush, Finger et al. 2000).

Irrigating with groundwater does offer benefits in terms of depleting water tables and reducing industry demand on surface water supplies, at least in the medium term. However, not all farmers have access to groundwater of suitable quality.

The other condition for the water saving approach to improving efficiency to be successful is that water is a constraint on production. If this condition is not met then there is little motivation to reduce water use. In our discussions with dairy farmers it became clear that time is the major constraint faced by most farmers. It also became clear that most farmers have rights to more irrigation water per hectare than they actually require. This means, after labour, land is much more of a constraint on expanding farm production than access to irrigation water. Consequently, there is no compelling reason for most dairy farmers to adopt water saving technologies or practices.

This conclusion suggests that variations in water use efficiency across dairy farms are unlikely to be associated with differences in irrigation technology or practice. This is consistent with the findings of Armstrong, Knee et al. (1998). They found weak relationships at best between efficiency of water use and irrigation layout and practice.

The second approach to increasing the efficiency of water use is to increase farm production without increasing the amount of water used. This means increasing the use of other farm inputs to complement the use of water. This second approach requires developing technologies and practices that are primarily *water augmenting*. Practices such as using fertiliser on pastures and purchasing supplementary feeds and concentrates are water augmenting because they enable farmers to carry higher stocking rates without substantially increasing water use. Through these practices farmers can increase water use efficiency by increasing milk production while maintaining a relatively constant level of water use.

Again, two important conditions must be met if the water augmenting approach to improving efficiency is to be successful. The first is the availability of appropriate techniques and practices. Examples are using fertiliser, supplementary feeding and growing fodder crops. The second condition is that these techniques and practices provide relief from a major production constraint. For example, the purchase of supplementary feeds provides a means of overcoming the constraint imposed by the limited area of land available to a dairy enterprise.

As water is not limiting, the adoption of water augmenting technologies and practices is driven by the need to overcome a production constraint in order to raise farm production and profits. Such technologies and practices are not adopted out of a desire to save irrigation water or to increase water use efficiency *per se*. The increase in efficiency of water use that accompanies the adoption of water augmenting technologies and practices is incidental. The adoption of such technologies and practices is motivated by the need to overcome a key constraint on production such as those imposed by limited labour or land resources.

This conclusion suggests that variations in water use efficiency across dairy farms are likely to be associated with differences in practices such as fertiliser use, feeding of supplements and fodder production. Armstrong, Knee et al. (1998) found a relationship between fertiliser use and efficiency of water use when adjusted for purchased feeds. We found strong relationships between water use efficiency, the use of fertiliser and the feeding of supplements with their data (see appendix A).

To summarise, the efficiency of water use can be increased in two ways. One way is to adopt technologies and practices that will reduce water use without reducing farm production. The suite of irrigation technologies and practices currently available do not offer major water savings at the individual farm level with the exception of spray irrigation on sandy or hilly country. Furthermore, reducing water use is not an imperative for most farmers as water is not a major production constraint on most dairy farms.

A second way in which the efficiency of water use can be increased is by adopting technologies and practices that will increase farm production without increasing water use. A number of practices of this type are currently available including the use of fertiliser on pasture and the feeding of supplements. Our work shows the motivation for adopting these practices is a need to overcome production constraints imposed by labour or land in order to increase farm production.

Note that farmers will only be highly motivated to adopt water saving technologies or practices under two conditions. One condition is if adoption of such technologies or practices provides relief from a major production constraint (such as labour). The other is if pricing or rationing policies are introduced that restrict farmers' access to irrigation water to the point where water becomes a key constraint on production.

In conclusion, dairy farmers are not compelled to reduce water use because it appears water is not a key factor limiting production on most farms. If reducing water use to reduce the environmental effects of irrigation is a major industry and social objective then farmers access to water must be limited, by pricing or rationing, to the point where it does constrain production. However, the adoption of irrigation practices such as laser grading, the installation of recycling dams and automatic irrigation does not create major water savings. Dairy farmers adopt these practices primarily because they offer substantial benefits in terms of saving time. This means that farmers will have to turn to water augmenting practices (such as supplementary feeding) to offset the production effects of any substantial reduction in water allocations.

If increasing water use efficiency to increase production is a major industry and social objective then policy and extension efforts should be directed toward encouraging the development and adoption of water augmenting practices. However, increasing water use efficiency does not necessarily lead to reduced water use. Therefore, increased water use efficiency does not necessarily reduce the environment effects of irrigation. Water augmenting practices include supplementary feeding, fodder crop production, and fertiliser and grazing management. Remembering that the motivation for adopting such practices is the need to overcome a labour or land constraint.

Managerial effectiveness and efficiency

In the preceding discussion we noted that while there is substantial variation in the efficiency of water use across dairy farms, this variation is largely unrelated to differences in irrigation technology or practice. This finding has led some to take the view that differences in water use efficiency are mostly due to differences in the 'managerial effectiveness' of farmers. Also, as we suggested, access to irrigation water is not restricting milk production on most dairy farms at present. This means that increasing water use efficiency will not be a high priority for most dairy farmers. Anecdotal examples of inefficient water use (such as irrigation water overflowing onto roads) are often tendered as support for this view. It follows that efforts to improve water use efficiency should focus on training farmers in irrigation management.

We believe, for a number of reasons, that this view strongly overstates the importance of managerial effectiveness in explaining variations in water use and water use efficiency. First, as we have already argued, much of the variation in water use efficiency can be attributed to differences in fertiliser practices and supplementary feeding practices. Second, dairy farmers are unlikely to waste irrigation water simply because increasing water use efficiency is not a high priority for them. Such behaviour is inconsistent with farming values of thrift and hard work. Armstrong, Knee et al. (1998), using estimates of pasture requirements based on rainfall and evaporation data, found the majority of farmers were not applying significantly more water than was necessary. Third, to the degree that water use per hectare does vary, this variation may be attributable to contextual factors reflecting the individual circumstances of farms such as soil type, farm topography, and variations in flow rates in district delivery channels. Fourth, farmers have invested heavily in laser grading, large bore outlets and recycling systems in order to reduce the amount of time they devote to irrigation. This combination is, by design, far less demanding of management expertise than the traditional, labour intensive irrigation layouts of narrow bays and small bore outlets.

It follows from this perspective that efforts to improve water use efficiency should concentrate on improving pasture, fertiliser and supplementary feeding technologies and associated management support systems. It also follows from this perspective that efforts to reduce the demands that irrigation places on farmers management skills should be directed towards improving water delivery systems and on promoting adoption of laser grading and recycling systems. The effect of efforts such as these to improve water use will be limited as long as access to irrigation water does not constrain farm production.

Conclusion

There is a concern in the dairy industry that supplies of irrigation water may limit the growth of the industry in the future. There is also a desire in the industry to reduce the undesirable environmental effects of flood irrigation. Consequently, the effective use of water resources by dairy farmers is a key aspect of the industry's plan for achieving sustainable resource management and substantial resources have been invested to identify methods for increasing the efficiency of water use on dairy farms.

A range of improved practices for irrigating dairy farms have been developed in recent years. These include the laser grading of irrigation bays, the installation of automatic irrigation systems, the installation of recycling dams, spray irrigation, and scheduling irrigations using soil moisture monitoring. Some practices, such as laser grading, have been widely adopted while other practices, such as automatic irrigation, have not been as popular.

Our objective in this study was to identify and understand the factors that influence the adoption of irrigation practices on dairy farms. To this end we interviewed a number of researchers, extension professionals and farmers. During discussions with farmers it became clear that increasing water use efficiency is not a high priority for most farmers. This is because water is not a limiting factor on most dairy farms.

Our discussions with farmers also revealed that most of the irrigation practices we were investigating are unlikely to generate significant water savings on individual farms if adopted (excepting spray irrigation on hilly or sandy country). Furthermore, farmers clearly indicated they are adopting the more popular of these practices (laser grading, recycling systems in particular) primarily to reduce the time they need to spend irrigating. We found that farmers are unlikely to adopt soil moisture monitoring either because the available methods are no more accurate than their experience, or they are impractical to use because many farmers cannot water on demand.

It follows that improvements in water use efficiency stem mainly from changes in pasture, fertiliser, fodder production and supplementary feeding practices (water augmenting technological change) and not from reduced water use. This conclusion is consistent with the findings of other studies. This implies that research and extension efforts to increase water use efficiency should concentrate on the development and adoption of water augmenting practices rather than attempting to reduce water use by focusing on irrigation practice and management.

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Appendix

Water Use efficiency

We report here on an analysis of a sub-set of the data collected by Armstrong, Knee et al. (1998). The analysis was undertaken to determine whether there are relationships among water use efficiency, irrigation layout, fertiliser use and supplementary feeding. We would like to thank Daniel Armstrong and Jacqui Knee for making their data available to us and for assisting us with the analysis.

There are a number of approaches to identifying relationships between water use efficiency and factors such as irrigation layout and fertiliser use. One approach is to estimate a single regression equation with efficiency as the dependent variable and layout, fertiliser use and so on as explanatory variables. This approach can be problematic when correlations between the explanatory variables is high. Also, the results of this approach are often difficult to interpret. Another approach is to view water use efficiency as the outcome the interaction between a number of factors and to construct and estimate equations for each of these factors. This is the approach we adopted.

We interpreted water use efficiency as milk production per unit of irrigation water applied. Milk production is the outcome of milk produced per cow and stocking rates. Hence, water use efficiency is the outcome of irrigation water used per hectare, milk production per cow and the stocking rate. That is:

Milk / Water = (Milk per cow * cows per hectare) / (Water per hectare)

We constructed and estimated separate equations for milk produced per cow, water use per hectare and the stocking rate. We hypothesised that the stocking rate depends on water use, fertiliser and purchased feed as these represent production of energy.

We hypothesised similarly that milk produced per cow depends on water use, fertiliser, purchased feed and the stocking rate. A higher stocking rate was expected to reduce milk production per cow. We hypothesised that water use depended on the stocking rate and fertiliser (higher stocking rates requiring higher pasture production consumption) and on irrigation layout (length and slope of bays, laser grading, recycling dams, and soil type).

The equations for water use per hectare, milk yield per cow and stocking rate were estimated using data for farms with irrigated perennial pasture only. Water use was recorded surface irrigation water and groundwater applied per hectare. Milk yield was recorded total milk production divided by the number of milking cows. Milk yield was not adjusted for non-milking stock. Stocking rate was the number of milking cows per hectare. Fertiliser was the total amount of phosphorus, nitrogen, potassium, sulphur and calcium applied per hectare. Supplementary feeding was the percentage of total farm energy from off-farm feeds. Farm layout was described by variables representing the length and slope of irrigation bays, area of farm lasered and area of farm draining to a recycling dam. A dummy variable representing soil type and a dummy variable representing the district in which farms were located were also included in the analysis.

Screening for outliers revealed two farms that reported levels of water use significantly greater than other farms (17 megalitres per hectare). Consequently, these two farms were excluded from the analysis.

The equations were estimated using multiple regression analysis available in SHAZAM (White, Haun et al. 1987). The parameter estimates are reported below. Values in parentheses are t-ratios. None of the variables describing farm layout were found to be statistically significant. The variable representing soil type was also found to be insignificant. Consequently, these variables were dropped from the final estimated equations. Each of the final equations is statistically significant and the estimated parameters are significant at the 5 per cent level in most instances.

The estimated equations for water use (see equations 1 and 4 below) were similar for both years and explain nearly 40 per cent of the variation in water use across farms in each year. The estimates indicate that water use is related to district location and stocking rate with use increasing as the stocking rate is increased.

The estimated equations for stocking rate (see equations 3 and 6) were similar for both years and also explain nearly 40 per cent of the variation in stocking rates across farms. The estimates indicate that stocking rates are strongly related to water use and purchased energy in the form of supplementary feed. If water use is indicative of pasture production then these equations simply indicate that higher stocking rates are supported by increased pasture production and higher purchases of supplements. A significant relationship was not identified between stocking rate and the rate of application of fertiliser.

The estimated equations for milk produced per cow (see equations 2 and 4) were different for each year. The equation for 1994/5 explains 40 per cent of the variation in stocking rates across farms in that year. The equation for 1995/6 on the other hand only explains 25 per cent of the variation in stocking rates across farms in that year. The estimates indicate that milk production per cow is strongly related to purchased energy, water use and stocking rates. There appears to be a relationship between milk per head and fertiliser use but this relationship may be less stable from year to year.

The estimates indicate that higher milk production per cow is supported by applying higher rates of fertiliser, greater purchasing of energy from off-farm in the form of supplementary feed, and by higher applications of water to pastures. However, higher stocking rates have a depressing effect on milk production per cow.

In conclusion, the results indicate that water use efficiency is primarily related to pasture and feed management through farmers' fertiliser programs and their purchasing of supplementary feed. By purchasing greater amounts of feed and applying higher rates of fertiliser, farmers are able to support higher stocking rates and obtain higher milk production per cow.

The results also indicate that there is an indirect relationship between water use and water use efficiency. The major driver of water use is stocking rate. Higher stocking rates are associated with higher levels of water use. This probably reflects higher levels of pasture production. No significant relationships were detected between water use and farm layout.

The implication that follows from these results is that variations in water use efficiency are mainly influenced by water augmenting practices such as fertiliser use and supplementary feeding. Irrigation layout and management appear to have much less of an influence on water use efficiency.

Table 1. Estimated equations (1994/95)

1. WATER = 12.3 + 1.46 * STOCK - 1.93 * DISTRICT
   (5.03) (1.38)
   $R^2 = 0.38$ F = 13.66, P = 0.00

2. MILK = 3614. + 29.37 * FERTILISER + 38.29 * ENERGY
   (2.66) (2.98)
   -555.43 * STOCK + 137.69 * WATER
   (2.86) (1.81)
   $R^2 = 0.40$ F = 7.21, P = 0.00

3. STOCK = 0.38 + 0.22 * WATER + 0.02 * ENERGY
   (4.59) (1.83)
   $R^2 = 0.39$ F = 14.74, P = 0.00

Table 2. Estimated equations (1995/96):

4. WATER = -11.38 + 1.46 * STOCK + 5.53 * DISTRICT
   (4.38) (2.95)
   $R^2 = 0.39$ F = 14.66, P = 0.00

5. MILK = 4019. - 1.40 * FERTILISER + 41.58 * ENERGY
   (0.18) (3.36)
   -475.51 * STOCK + 101.83 * WATER
   (2.19) (1.42)
   $R^2 = 0.25$ F = 3.52, P = 0.01

6. STOCK = 1.17 + 0.16 * WATER + 0.02 * ENERGY
   (3.86) (2.30)
   $R^2 = 0.35$ F = 12.30, P = 0.00

IRRIGATION SYSTEMS, IRRIGATION MANAGEMENT AND DAIRY FARMING

Second Report

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Executive Summary

In this study we investigated the major forces driving the adoption of irrigation practices by dairy farmers. A mail survey was sent to approximately 2500 dairy farmers from the Northern Irrigation Region of Victoria. The response rate was 35 per cent.

Interviews with farmers in the first stage of this project suggested that saving time is the major concern of dairy farmers. The results of the survey supported that finding. Saving time was identified as a major factor in the adoption of laser grading and the installation of recycling dams (as being able to irrigate on demand). Saving time, especially at night, was identified as the most important factor influencing the adoption of water babies and automatic irrigation.

Managing high water tables and saline groundwater was identified as a factor in laser grading and the installation of recycling dams, and irrigating with groundwater. It also appears the successful use of evaporation information and soil moisture monitoring occurs where the use of these techniques is motivated by a need to manage high water tables and saline groundwater.

Saving water was identified as a factor in the adoption of laser grading, especially among those farmers whose production had been limited by poor farm layout and the presence of humps and hollows in irrigation bays. Saving water was also identified as the major factor in the adoption of groundwater irrigation. Saving water was a factor in the adoption of recycling dams, especially when dams formed an integral part of a groundwater irrigation system. However, saving water did not appear to be a major factor in the adoption of water babies or automatic irrigation. Saving water also did not appear to be a factor *per se* in the adoption of evaporation information or soil moisture monitoring for irrigation scheduling.

A substantial proportion of the dairy farmers in the sample do feel their water right is insufficient, nearly 50 per cent. However, given that most farmers have laser graded the majority of their properties and that most farmers have also installed recycling dams, the potential to influence water use efficiency by decreasing water use on farm seems limited. Farmers do not view the use of water babies, automatic irrigation or irrigation scheduling using evaporation information or soil moisture monitoring as contributing greatly to increasing water use efficiency.

These findings mean that, apart from irrigating with groundwater, the potential for farmers to respond to any decline in the availability of irrigation water by changing irrigation practices is limited. This suggests, in our view, the only possible actions farmers might take in responding to limited water supplies would be to purchase additional water or to increase their use of fertiliser and purchased feed supplements (such as grains and concentrates). While these actions would increase water use efficiency, they would not reduce water use *per se*.

The scope for increasing water use efficiency by improving the management of irrigation also seems limited. The combination of laser grading and recycling dams is far less demanding of management expertise than the traditional, labour intensive irrigation layouts

of narrow bays and small bore outlets. The high rate of adoption of this combination of practices means that, over time, the influence of irrigation management on variations in water use per hectare will become less and less important. Such variations will increasingly reflect differences in contextual factors between farms such as soil type and farm topography.

This means that variations in water use efficiency should be related to the management of pastures, fertiliser and supplementary feeding technologies rather than water use per hectare. This is consistent with the findings of (Armstrong, Knee et al. 1998). We concluded from these results that efforts to improve water use efficiency should be directed toward pasture management, fertiliser management and management of supplementary feeding rather than irrigation management.

The high level of adoption of laser grading and recycling dams suggests there is little reason to allocate extension resources to promoting these practices. There also seems to be little reason to direct extension resources to promoting the use of groundwater for irrigation. Irrigating with groundwater is motivated either by a problem with too much water (high watertables and salinity) or a problem with too little water (insufficient water right). Consequently, the adoption of groundwater irrigation is prompted by environmental factors (policy and biophysical). Hence the adoption of groundwater irrigation is unlikely to be influenced by extension activities when these factors are absent.

There is little reason to direct extension resources to promoting the use of spray irrigation unless significant savings can be demonstrated in the time farmers would need to spend irrigating. However, if spray irrigation is shown to generate substantial savings in water use it might be promoted to dairy farmers concerned about insufficient water right, especially those without access to groundwater suitable for irrigation.

There appears to be potential for extension activities to promote the adoption of water babies and automatic irrigation. With respect to water babies, activities promoting their use on lasered bays that do not empty into recycling dams or some form of drain should be considered. More importantly, extension activities promoting the use of water babies as a means of saving time, especially when irrigating at night, should be considered. There is some evidence that the adoption of water babies is a precursor to the adoption of automatic irrigation. This suggests activities promoting water babies could be targeted at potential adopters of automatic irrigation.

With respect to automatic irrigation, extension activities promoting the use of automatic irrigation as a means of saving time, especially among farmers who have to irrigate at night, should be considered. Of the farmers who irrigate at night, those with large dairy properties and who use water babies, could be targeted as being the most likely to adopt automatic irrigation.

Finally, extension activities aimed at promoting the use of evaporation data or soil moisture monitoring to assist irrigation scheduling should be targeted at farmers who have problems with high water tables or salinity, especially those who are able to irrigate on demand.

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We are indebted to the dairy farmers who participated in the study by being kind enough to grant us interviews.

All errors and omissions remain the responsibility of the authors.

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Irrigation Systems, Irrigation Management

and Dairy Farming

Introduction

In this report we describe the results from the second stage of a study into the adoption of a range of improved practices for irrigating dairy farms. These include the laser grading of irrigation bays, the installation of automatic irrigation systems, the installation of recycling dams, spray irrigation, the use of water babies, and soil moisture monitoring or evaporation information to assist in scheduling irrigations. Some practices, such as laser grading, have been widely adopted (Douglass, Poulton et al. 1998). Other practices, such as automatic irrigation, have not been as popular (Douglass, Poulton et al. 1998).

In the first stage of the study we interviewed dairy farmers, research and extension staff to identify the factors that influence the adoption of irrigation systems and management practices (Kaine and Bewsell 2000). In this, the second stage of the study, we conducted a mail survey of dairy farmers in the Goulburn and Murray Valleys of Victoria. The purpose of the survey was to quantify the relative importance of the factors influencing the adoption of irrigation systems and management practices. The findings from that survey are described in this report.

In the next section of the report the mail questionnaire we used to obtain the data is described and the characteristics of those dairy farmers who responded to the survey are outlined. The results from the statistical analysis of the data are presented in a series of separate sections relating to:

- laser grading of irrigation bays,
- the installation of recycling dams,

- irrigating with groundwater,
- the use of water babies,
- installation of automatic irrigation systems,
- scheduling irrigations using soil moisture monitoring and evaporation information, and
- spray irrigation.

In the final section of the report some implications of the results for extension in the dairy industry are proposed.

The questionnaire

The survey questionnaire was divided into a number of sections. In the first and second sections of the booklet we sought information on some basic farm characteristics such as total area and area of permanent pasture and annual pasture, herd size, calving pattern, milking shed design, time spent milking and so on (see appendix A). The third section was designed to elicit information about irrigation on the farm such as time spent irrigating, method of ordering irrigation water, reliability and consistency of irrigation supplies and scheduling of irrigations. Respondents who used, or had tried using, evaporation information or soil moisture monitoring to schedule irrigations were asked to describe their experiences.

In the following sections of the survey information was sought on laser grading, spray irrigation, water babies, automatic irrigation, recycling dams and groundwater irrigation respectively. Respondents were asked to indicate which of the key factors that were identified in the first stage of this project as influencing the adoption of these systems and practices best described their reasons for adopting them.

The questionnaire was printed in the form of a 20 page booklet and mailed with a cover letter explaining the project and providing contact details.

Sampling and response rate

The questionnaire was distributed to all irrigated dairy farms in the Goulburn and Murray Valleys of Victoria. The population of farmers in the target area is approximately 2800.

The questionnaires were mailed in May 2000 with a reminder posted four weeks later. The study and survey were also publicised through the local print media and industry newsletters. Five questionnaires were returned with incorrect addresses or from people who were not dairy farmers. This gave an effective mail out of 2,523 questionnaires. A total of 873 questionnaires had been returned some ten weeks after the initial mailing. This represents a response rate of 35 per cent.

Approximately 44 per cent of returns came from Shepparton area, 11 per cent from Rochester-Campaspe area, 27 per cent from the Murray Valley and 18 per cent from the Kerang-Cohuna area.

Some general characteristics of the sample are reported in table 1. In the table the average area of farms, the average area irrigated and the average areas of irrigated permanent pasture, annual pasture, fodder and grain crops are reported. The results indicate that most dairy farms consist of a combination of irrigated permanent and annual pastures with some dryland pastures for dry cows and young stock. This pattern is consistent with the results reported by (Armstrong, Knee et al. 1998). These results also indicate that irrigated dairy farms are, on average, smaller than dryland dairy farms (Kaine and Niall 1999).

The average herd size and stocking rate are also reported in table 1. The average herd size in our sample is substantially greater than the average herd size of 156 cows reported by (Armstrong, Knee et al. 1998) but similar to the average size of 167 cows reported by the (Martin, Riley et al. 2000) for the Goulburn-Murray area in Victoria. The average herd size on irrigated farms in our sample is similar to dryland farms however the stocking rate at 2.2 cows per hectare is slightly higher than on irrigated farms at 1.8 cows per hectare (Kaine and Niall 1999).

In table 2 the proportion of farms in each month with cows calving are reported. Spring calving is clearly the most common period for calving. Almost one third of farmers also have cows calving in autumn. These calving patterns correspond with the calving and milk production patterns reported by (Armstrong, Knee et al. 1998).

Table 1: Selected farm characteristics

Average farm area (ha)	125 (11.2 - 1291.0)
Average irrigated area (ha)	100.9 (10.8 - 995.0)
Average area of irrigated permanent pasture (ha)	61.4 (0.0 - 333.0)
Average area of irrigated annual pasture (ha)	29.9 (0.0 - 650.0)
Average area of irrigated fodder crop (ha)	4.4 (0.0 - 320.0)
Average area of irrigated grain crop (ha)	4.0 (0.0 - 688.0)
Average area of dryland pasture (ha)	13.5 (0.0 - 800.0)
Average herd size (head)	192 (1.0 - 1200)
Average stocking rate (head/ha)	2.2 (0.01 - 8.86)

Table 2: Calving pattern

Month	Per cent of farms
January	2.8
February	3.7
March	21.8
April	29.9
May	19.4
June	8.7
July	25.9
August	95.3
September	88.9
October	55.5
November	15.4
December	5.7

Approximately 80 per cent of milking herds consisted of Friesians with another 9 per cent being Jerseys. Dairy farmers spent about four hours a day milking and another two hours each day preparing for milking and cleaning dairies following milking. Nearly 90 per cent of farms had a herringbone dairy. Most farms relied on family labour to run the farm with only 19 per cent of farms having a full-time employee. However, a substantial proportion of farms did use hired labour to assist in milking with 27 per cent of dairy farmers reporting they employed relief milkers and another nine per cent employing a permanent casual milker.

Approximately 54 per cent of farmers who responded to the survey indicated they had a problem with insufficient water right. Approximately 28 per cent reported problems with high water tables and 25 per cent reported problems with saline groundwater. Only 9 per cent of farmers reported problems with unreliable channel supplies.

Rate of adoption of improved irrigation techniques and practices

In figure 1 the proportion of farmers in the sample who had adopted each of the improved irrigation practices is presented. Virtually all farmers have invested in laser grading and recycling dams. A substantial proportion of farmers, almost 40 per cent, irrigate with groundwater. A smaller proportion of farmers, around 20 per cent, use water babies.

Although about 14 per cent of farmers have tried using evaporation information to schedule irrigations at one time or another, however less than ten per cent of farmers use this technique. Only one per cent of farmers use soil moisture monitoring to help them schedule their irrigations.

Approximately ten per cent of farmers have invested in automatic irrigation. Two per cent of farmers use spray irrigation.

We found the rate of adoption of these practices and technologies was similar across the different areas in the sample with one exception. The exception was the installation of groundwater pumps and groundwater irrigation. A higher proportion of farmers in the Murray Valley and Rochester-Campaspe areas have installed groundwater pumps and irrigate with groundwater than in the Shepparton and, in particular, the Kerang-Cohuna areas.[1] This reflects the availability of suitable groundwater supplies across these regions.

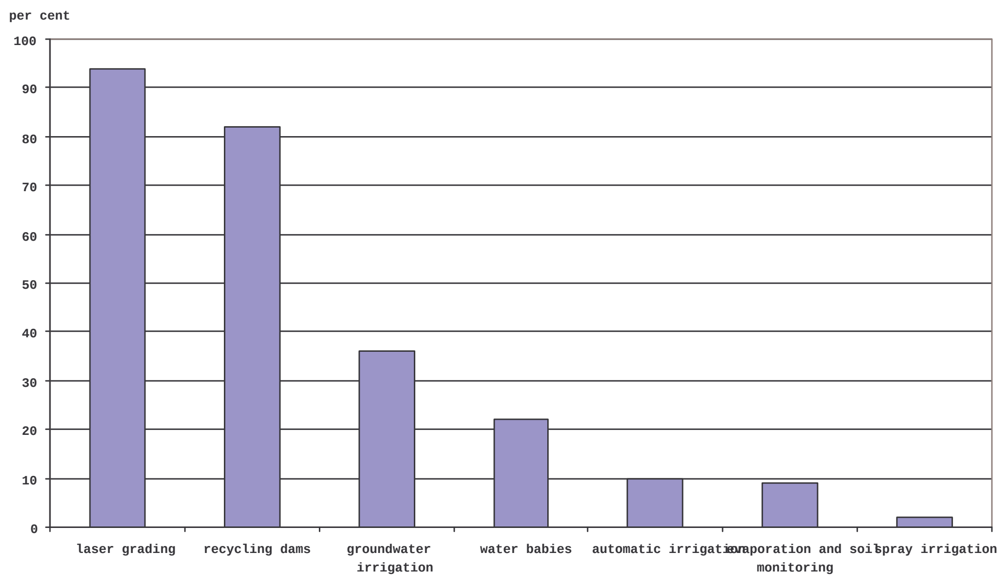

Figure 1: Adoption rates

Classifying farmers into segments is impractical with respect to scheduling irrigations using evaporation information or soil moisture monitoring, installing automatic irrigation, or installing spray irrigation. This is because such small proportions of farmers use these techniques and practices. Consequently we did not conduct a segmentation analysis for these techniques and practices.

Segments for laser grading

Interviews with dairy farmers in the qualitative stage of this study suggested that saving time irrigating was the main reason for adopting laser grading. Most dairy farms were originally designed with numerous narrow, short bays and small bore water outlets. This design has become increasingly impractical over time with

[1] For groundwater pumps: Shepparton 29 per cent, Rochester-Campaspe 39 per cent, Murray Valley 50 per cent and Kerang-Cohuna 8 per cent, with χ^2=76.8, p=0.00. For groundwater irrigation: Shepparton 32 per cent, Rochester-Campaspe 43 per cent, Murray Valley 60 per cent and Kerang-Cohuna 8 per cent, with χ^2=84.7, p=0.00.

increases in farm size and cow numbers. As a consequence, many dairy farmers have used laser grading to reduce the amount of time they have to spend irrigating by consolidating a large number of narrow, short bays into a smaller number of longer, wider bays and improving farm layout.

Other reasons that were advanced for laser grading were to remove humps and hollows to improve water flow, to regrade land that had been poorly graded in the past, to be able to irrigate new land, and to save water and increase milk production.

In the survey farmers were supplied with a list of reasons for laser grading and were asked to indicate which of these reasons best described why they had laser graded their farms (see appendix A). The responses to this question were used to classify farms into adoption segments.

Laser grading contributes to saving water by improving the speed and uniformity of water flow over irrigation bays. This results in improved pasture growth. This, together with resowing pastures, results in increased milk production. This implies that laser grading is likely to have the greatest impact on water use and milk production where laser grading has been used to improve farm layout and to improve water flow by removing humps and hollows. It also implies that laser grading is likely to have only a marginal impact on water use and milk production on farms with a good layout and satisfactory water flow because of an absence of humps and hollows.

Consequently, we segmented farmers on the basis of whether they indicated they used laser grading to improve farm layout, to improve water flow, to save time, to irrigate new land, to manage a salinity problem, or to regrade land that had not been properly graded. We then tested for significant differences across the segments in terms of the proportion of farmers who nominated saving water and increasing milk production as additional reasons for laser grading.

Nearly 60 per cent of farmers in the sample nominated saving water or increasing milk production as reasons for laser grading, most nominating both reasons. Only 4 per cent of farmers gave saving water as their only reason for laser grading and only 3 per cent of farmers gave increasing milk production as their only reason for laser grading. Note that 94 per cent of respondents had used laser grading on their farm. On average, respondents had laser graded approximately 65 per cent of the irrigated area of their farm. This is consistent with the results reported by (Armstrong, Knee et al. 1998).

The segmentation analysis was conducted using a monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987) which is specifically designed for use with dichotomous data.[2] This algorithm works by placing all respondents in one segment and then dividing respondents into successively smaller and smaller segments depending on their characteristics. A 'scree' test indicated that four segments were present in the sample (Aldenderfer and Blashfield 1984).

The formation of the four segments is illustrated in figure 2 and the profiles of the farmers in each segment, in terms of their reasons for adopting laser grading are presented in figure 3.

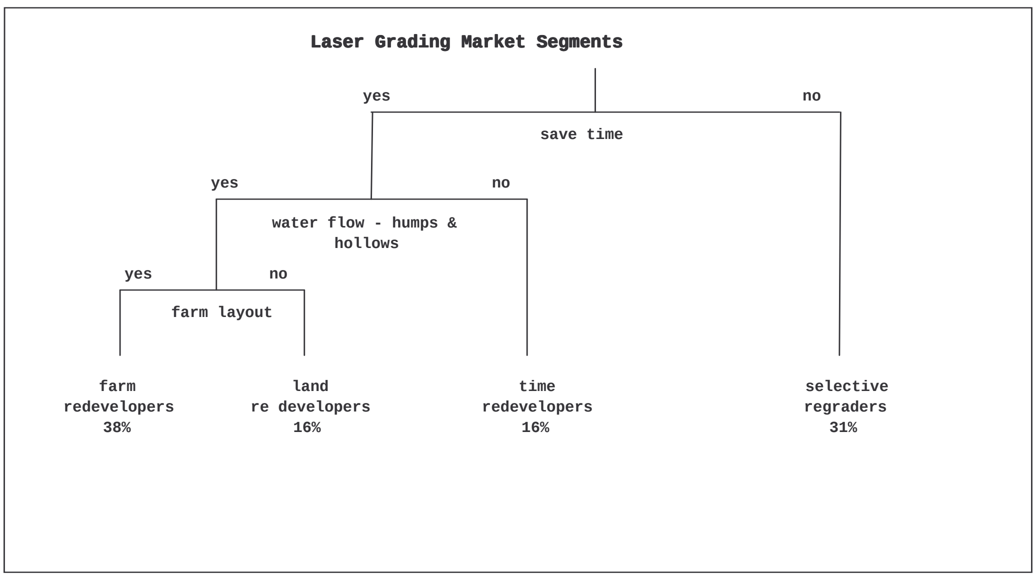

Figure 2: Formation of laser grading segments

The first of the segments, which is shown in the lower left corner of figure 2, is the 'farm redevelopment' segment. This segment consists of farmers who were laser grading to save time and labour irrigating by improving farm layout and reducing the

[2] The similarity coefficient used was squared Euclidean distance.

number of bays on their farm and who wanted to improve water flow on their paddocks by removing humps and hollows. Over half of the farmers in this segment were also using laser grading to convert dryland to irrigated pasture. Approximately 20 per cent of the farmers in this segment were also using laser grading to overcome problems with salinity. The farmers in this segment represented approximately 38 per cent of respondents.

The second segment consists of farmers who were laser grading to save time and labour irrigating by reducing the number of bays on their farm and who wanted to improve water flow on their paddocks by removing humps and hollows. Nearly half of the farmers in this segment also used laser grading to convert dryland to irrigated pasture. The farmers in this 'land redevelopment' segment represented approximately 15 per cent of respondents.

The third segment consists of farmers who were laser grading to save time and labour irrigating simply by reducing the number of bays on their farm. Nearly half of the farmers in this segment also used laser grading to convert dryland to irrigated pasture. The farmers in this 'time redevelopment' segment represented approximately 16 per cent of respondents.

The fourth segment in the lower right corner of figure 2, is the 'selective regrading' segment. This segment consists of farmers who were laser grading to improve water flow on their paddocks by removing humps and hollows or by regrading land that had not been properly graded (see figure 3). Almost 30 per cent of the farmers in this segment also used laser grading to convert dryland to irrigated pasture. The farmers in this segment represented approximately 31 per cent of respondents.

The farmers in the 'farm redevelopment' and the 'land redevelopment' appear to be following a major redevelopment program. This suggests that a high proportion of the farmers in these segments would expect laser grading to lead to an increase in

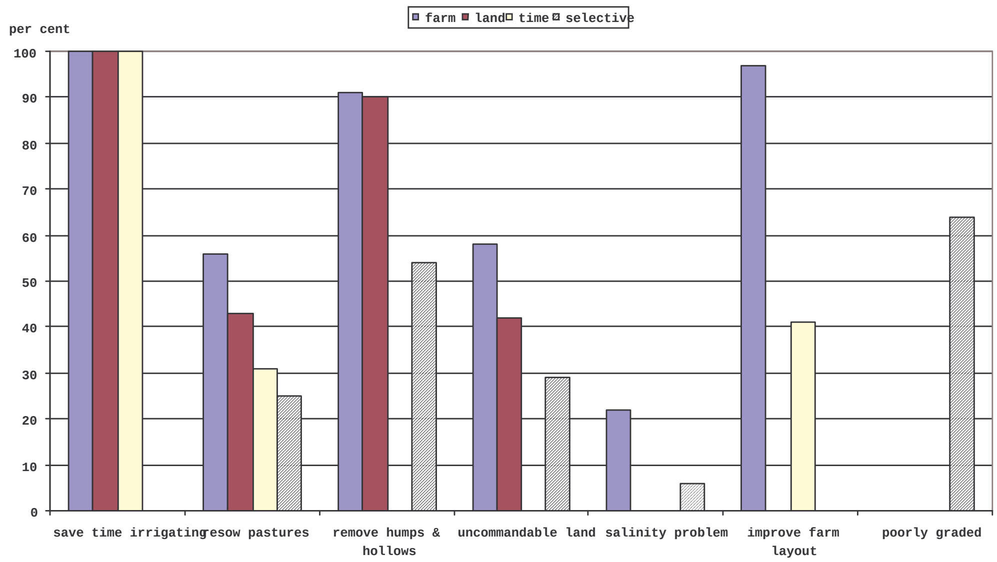

Figure 3 Attributes of laser grading segments

milk production and a decrease in water use. We would expect that a relatively smaller proportion of farmers in the 'time redevelopment' segment would expect to save water and a relatively smaller proportion of farmers in the 'selective regrading' segment would expect to save water or increase milk production. In figure 4 the proportions of farmers in each segment who indicated that one of the reasons why they laser graded was to save water or increase milk production are shown. The results presented in the figure are consistent with our expectations. The proportion of farmers reporting saving water and increasing milk production as reasons for laser grading is significantly higher in the 'farm redevelopment' and 'land redevelopment' segments.[3]

On average, the farms in each segment were similar in terms of total area and irrigated area. However, the proportion of the farm area that had been laser graded was significantly higher for farms in the 'farm redevelopment' and 'land redevelopment' segments.[4] Consequently, the area of land lasered on farms in these

[3] For saving water χ^2=115.6, p=0.00, for increasing milk production χ^2=109.8, p=0.00.
[4] $F_{3, 730}$=19.6, p=0.00

two segments was greater, on average, than on farms in the 'time redevelopment' or 'selective regrading' segment[5]. On average, the total area irrigated (home farm and out block) area was significantly greater on farms in the 'farm redevelopment' and 'land redevelopment' segments.[6]

No significant differences between the farms in each segment were found in terms of the area, on average, of perennial and annual irrigated pastures, stocking rates, area irrigated per person or cows milked per person.

We did find that the proportion of farmers reporting problems with high water tables, saline groundwater and insufficient water right was highest in the 'farm redevelopment' segment (see table 3).[7] We also found the proportion of farms reporting problems with high water tables and saline groundwater was lowest for the 'land redevelopment' segment. The proportion of farms reporting problems with insufficient water right was lowest for the 'time redevelopment' segment.

Table 3: Selected characteristics of laser grading segments

	Farm redevelopment	Land redevelopment	Time redevelopment	Selective regraders
Average water right/ha	4.01	3.64	3.74	3.99
Per cent of farms reporting problems with:				
Insufficient water right	63	47	41	56
Unreliable channel supply	12	8	7	8
High water tables	36	19	24	30
Saline groundwater	33	12	20	22

[5] $F_{3,\,634}$=3.1, p=0.03
[6] $F_{3,\,522}$=2.7, p=0.05
[7] For high water tables χ^2=13.0, p=0.00, for saline groundwater χ^2=22.5, p=0.00, for insufficient water right χ^2=19.4, p=0.00.

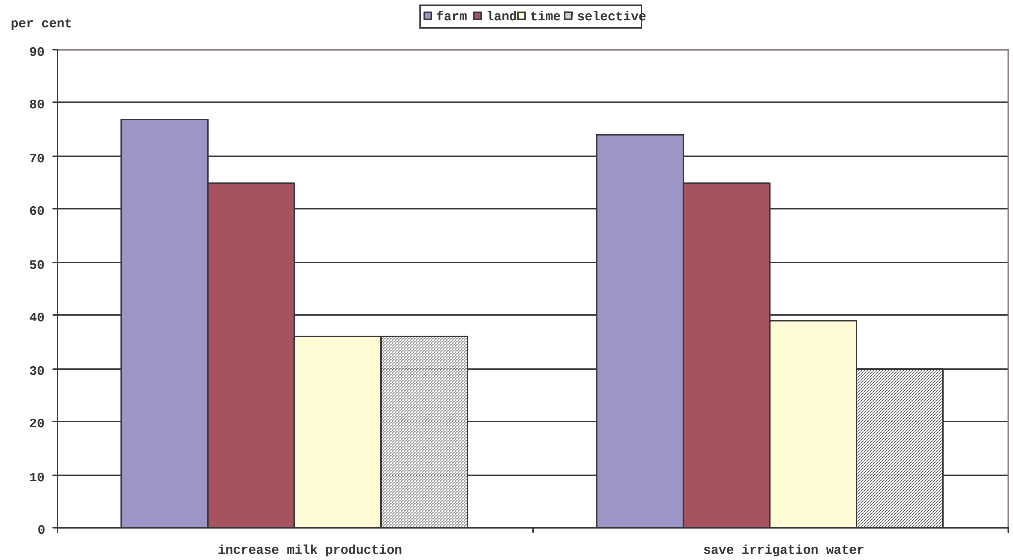

Figure 4: Increasing milk production and saving water as motivations for laser grading by segment

In conclusion, these results indicate that laser grading has been undertaken to save time irrigating by improving farm layout and consolidation of irrigation bays, and to save water and increase milk production by removing humps and hollows to improve the speed and uniformity of water flow over irrigation bays.

Segments for recycling dams

Over 80 per cent of dairy farmers in the sample have installed recycling dams. This is substantially higher than the 53 per cent reported by (Douglass, Poulton et al. 1998) for 1996/97. Interviews with farmers in the qualitative stage of this study suggested that farmers installed recycling dams for a number of reasons. These included to increase their control over the timing and rate of application of irrigation water (*ie* irrigate on demand), to conserve run-off or store groundwater to augment supplies of surface irrigation water, or to be able to irrigate from low yielding bores by storing groundwater prior to irrigation. Farmers may also install recycling dams to counter the risk of substantial water losses on irrigation bays that have been laser graded or to obtain soil for enlarging on-farm channels to irrigate lasered bays.

In the survey farmers were supplied with a list of reasons for installing recycling dams and were asked to indicate which of these reasons best described why they had installed a recycling dam (see appendix A). The responses to this question were used to classify farms into adoption segments with respect to recycling dams.

Again, the segmentation analysis was conducted using the monothetic divisive clustering algorithm available in CLUSTAN (Wishart 1987).[8] A ‘scree’ test indicated that five segments were present in the sample (Aldenderfer and Blashfield 1984).

The formation of the five segments is illustrated in figure 5. The profiles of the farmers in each segment, in terms of their reasons for installing a recycling dam, are presented in figure 6.

The first of these segments, shown in the lower left corner of figure 5, is the 'demand and store' segment. This segment consists of farmers whose reasons for installing a

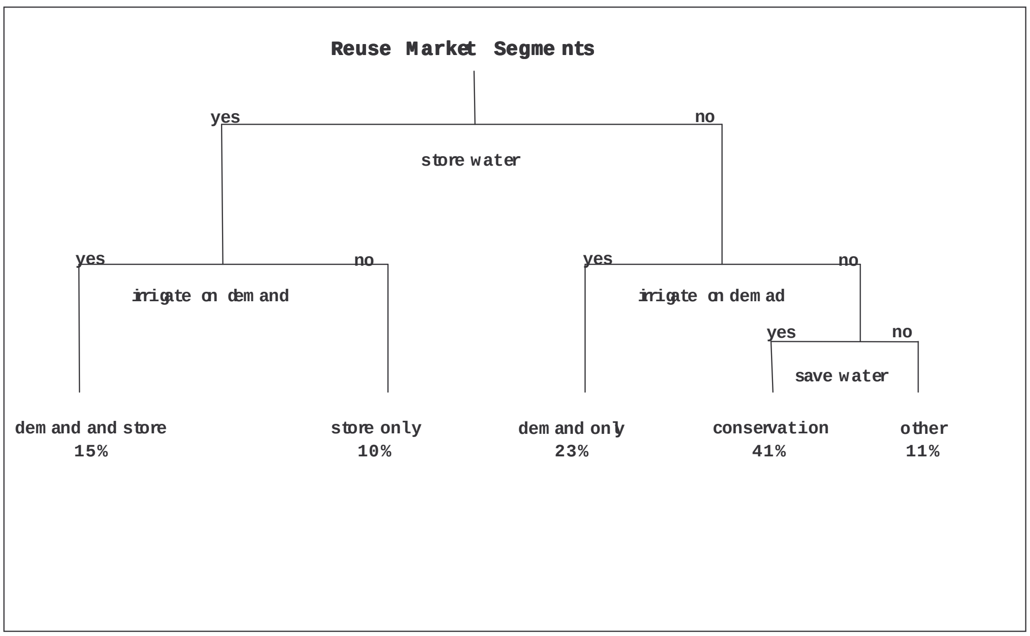

Figure 5: Formation of recycling dam segments

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[8] The similarity coefficient used was squared Euclidean distance.

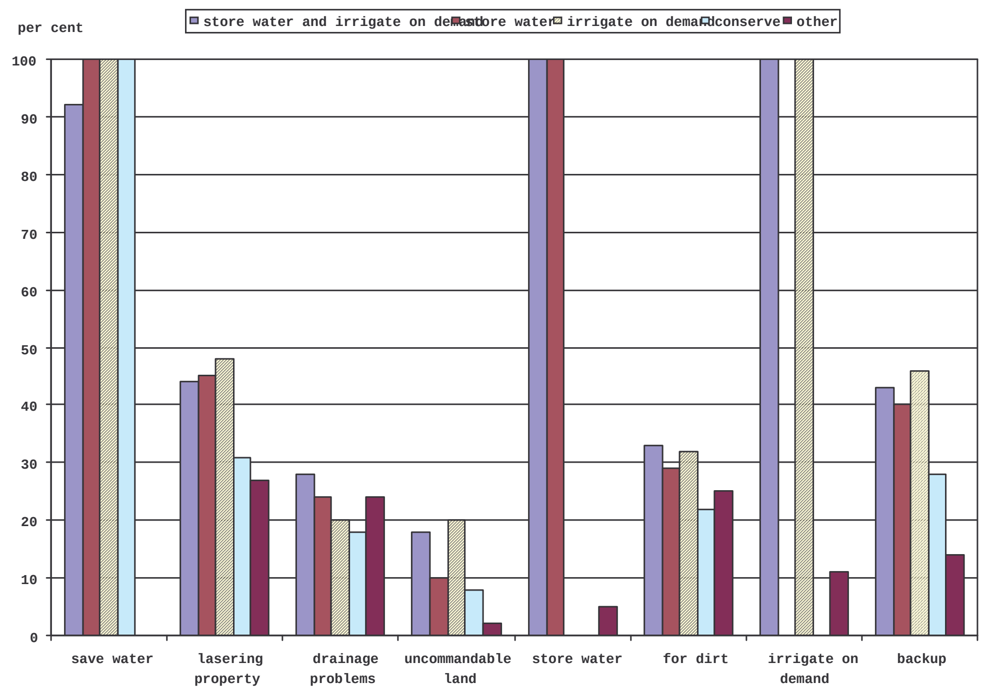

Figure 6: Attributes of recycling dam segments

recycling dam were to save irrigation water, and to store water so they can irrigate on demand. These farmers in this segment represented approximately 15 per cent of respondents with recycling dams.

On average, the water right per hectare of farmers in the 'demand and store' segment is the lowest of any of the segments (see table 4). A relatively high proportion of these farmers have a problem with insufficient water right or unreliable channel supplies. Consequently, the proportion of farmers in this segment who irrigate with groundwater is relatively high. Many farmers in this segment use recycling dams to shandy saline groundwater. Note that, on average, the farmers in this segment also spend relatively more time irrigating than farmers in most other segments.[9]

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[9] For difference in average reported water right $F_{4, 498}=3.3$, p=0.01. For insufficient water right $\chi^2=14.6$, p=0.01, for unreliable channel supply $\chi^2=11.8$, p=0.02, for irrigating with groundwater $\chi^2=24.4$, p=0.00, or saline groundwater $\chi^2=9.7$, p=0.05 and for shandying irrigation water $\chi^2=18.7$, p=0.00. For difference in average days irrigating $F_{4, 562}=2.3$, p=0.05.

The second segment consists of farmers who installed a recycling dam to save and store water for irrigation. The farmers in this ' store only' segment represented approximately 10 per cent of respondents with recycling dams.

The farmers in this segment also have a relatively low water right per hectare, on average (see table 4). Again, a relatively high proportion of these farmers have a problem with insufficient water right. Consequently, the proportion of farmers in this segment who irrigate with groundwater is relatively high. Again, many use their recycling dams to shandy their groundwater because it is saline.

The third segment consists of farmers who installed a recycling dam to be able to save run-off and irrigate on demand. The farmers in this ' demand only' segment represented approximately 23 per cent of respondents with recycling dams. A relatively high proportion of the farmers in this segment have a problem with unreliable delivery of irrigation supplies (see table 4). Note that, like the farmers in the first segment, the farmers in this segment spend relatively more time irrigating compared to farmers in most other segments.

Table 4: Selected characteristics of recycling dam segments

	Demand and store	Store	Demand	Conserve	Other
Average water right/ha	3.64	3.74	3.99	4.01	4.61
Days spent irrigating	3.59	3.24	3.68	3.23	3.51
Per cent of farms reporting problems with:					
Insufficient water right	62	68	55	46	46
Unreliable channel supply	12	4	13	9	-
High watertables	33	39	34	30	19
Per cent of farms:					
Irrigating with groundwater	60	43	34	28	37
With saline ground water	31	29	29	25	10
Shandying irrigation water	49	42	30	23	20
Can irrigate on demand from recycling dam	91	75	90	74	69
Can irrigate on demand by pumping ground water	44	30	27	20	30

The fourth segment towards the lower right corner of figure 5, is the 'conserving' segment. This segment consists of farmers who installed a recycling dam to be able to save run-off (see figure 6). The farmers in this segment represented approximately 41 per cent of respondents with recycling dams. The water right per hectare of farmers in this segment is close to average (see table 4). This suggests these farmers simply use their recycling dams to conserve and recycle any irrigation run-off and do not have a problem with insufficient water right *per se*. This is consistent with the proportion of farmers in this segment reporting they had a problem with insufficient water right being relatively low. Note also, that the proportion of farmers in this segment irrigating with groundwater is relatively low.

Finally, the fifth segment in the lower right corner of figure 5 is the only group of farmers who did not indicate that saving water was a reason for installing a recycling dam (see figure 6). The farmers in this segment installed a dam either because of drainage problems, they needed dirt for lane or channel construction, or because they were having their property laser graded. The farmers in this 'other' segment represented approximately 11 per cent of respondents with recycling dams.

The water right per hectare of farmers in this segment is relatively high (see table 4). This is consistent with the proportion of farmers in this segment reporting they had a problem with insufficient water right being relatively low. Note also, that the proportion of farmers in this segment irrigating with groundwater is relatively low. Note also, that a significantly lower proportion of farmers in this segment gave prevention of water losses on laser graded bays (*ie* backup) as a reason for installing a recycling dam.

Note that no significant differences were found among the segments in terms of the area irrigated, the area of out block irrigated or the area lasered, on average.

In figures 7 and 8 the associations between the laser grading segments and the recycling dam segments are presented.[10] In terms of the recycling dam segments an examination of figure 7 shows that the majority of farms in the 'store and demand'

[10] For associations among segments χ^2=62.2, p=0.00.

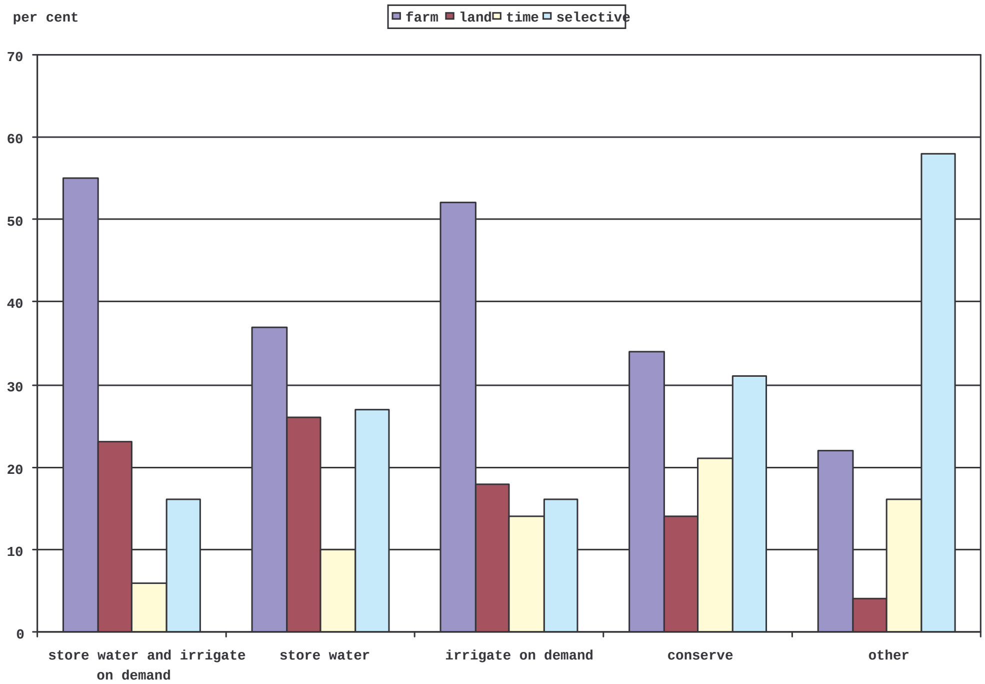

Figure 7: Mix of laser grading segments in each recycling dam segment

segment are from the 'farm redevelopment' and 'land redevelopment' laser grading segments. The same is the case for the composition of the 'demand only' recycling segment. The majority of farms in the 'other' recycling segment are from the 'selective regrading' segment.

On the whole, the pattern of laser grading segments across the recycling segments appears consistent with the different labour and water constraints that characterise the recycling segments.

In terms of the laser grading segments an examination of figure 8 shows that the majority of farms in the 'farm redevelopment' segment are from the 'store and demand' and 'demand only' recycling segments. The same is the case for the composition of the 'land redevelopment' segment. The majority of farms in the 'time redevelopment' segment are from the 'conserving' recycling segment. Finally, the majority of farms in the 'selective regrading' segment is from the 'conserving' and the 'other' recycling segments. Again, the pattern of association between the two sets of segments appears consistent in terms of labour and water constraints.

Recycling dams are impractical in some situations because of unsuitable soil types or topography. Approximately 47 per cent of farmers indicated that some section of their property did not drain to a recycling dam. This was mainly because the topography of the section made a dam impractical, the section emptied into a creek or drain, or because that section of the property had not yet been lasered or developed (see figure 9).

Approximately 17 per cent of farmers indicated that they did not have a recycling dam. Again, this was mainly because the topography of the property made a dam impractical, the property emptied into a creek or drain, or because the property had not yet been lasered or developed (see figure 10). The proportion of farms without a reuse dam was significantly higher in the 'selective regrading' segment (see figure 11).

In conclusion, these results indicate that recycling dams are installed for a number of reasons. Over 40 per cent of farmers who have installed recycling dams did so primarily to conserve and recycle irrigation run-off. About 25 per cent have installed dams to store run-off or groundwater to augment insufficient irrigation water rights.

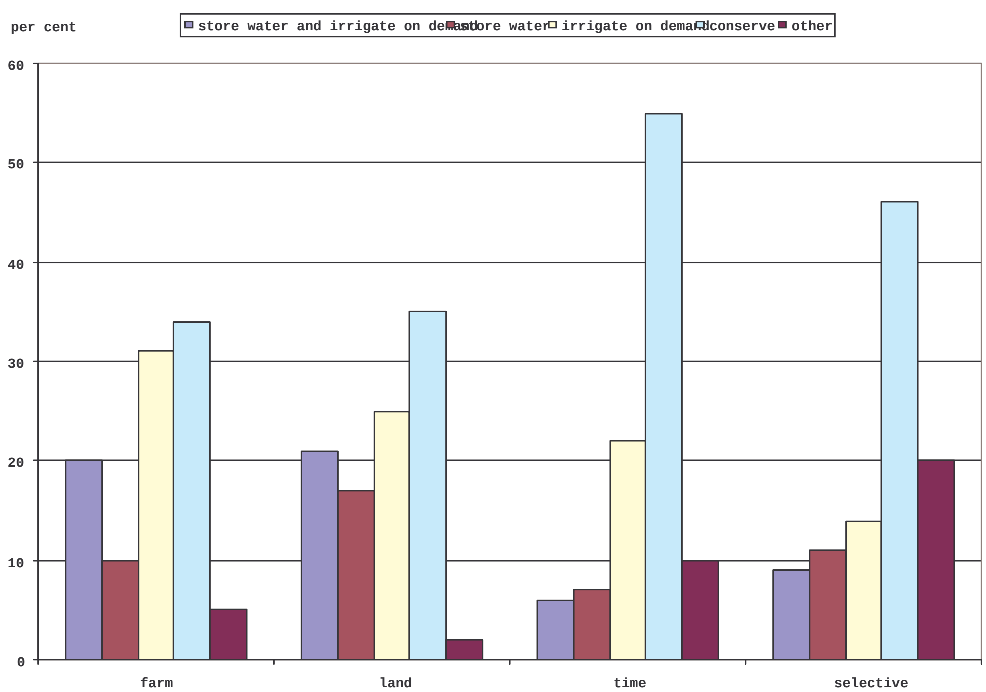

Figure 8: Mix of recycling dam segments in each laser grading segment

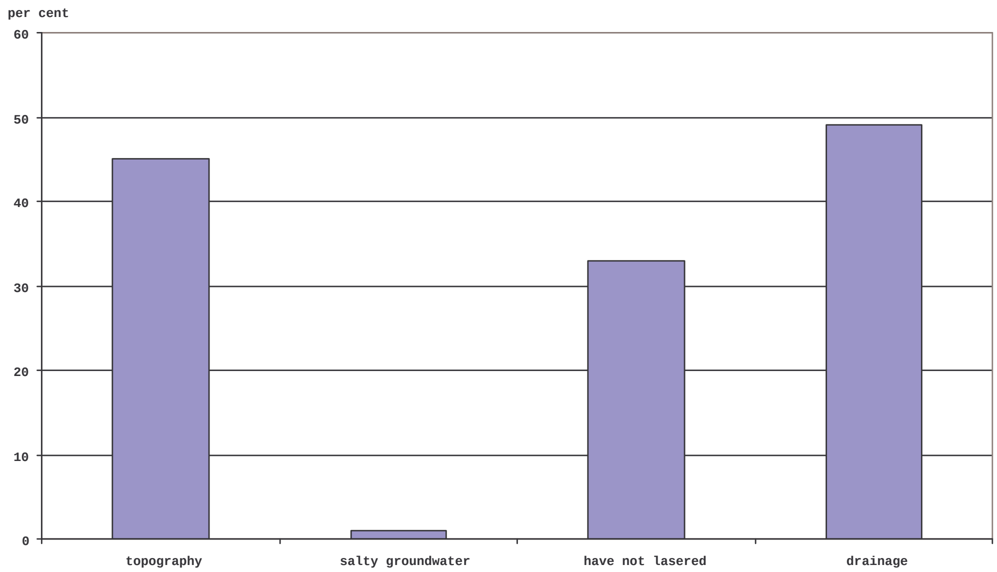

Figure 9: Reasons for section of farm not draining to a recycling dam

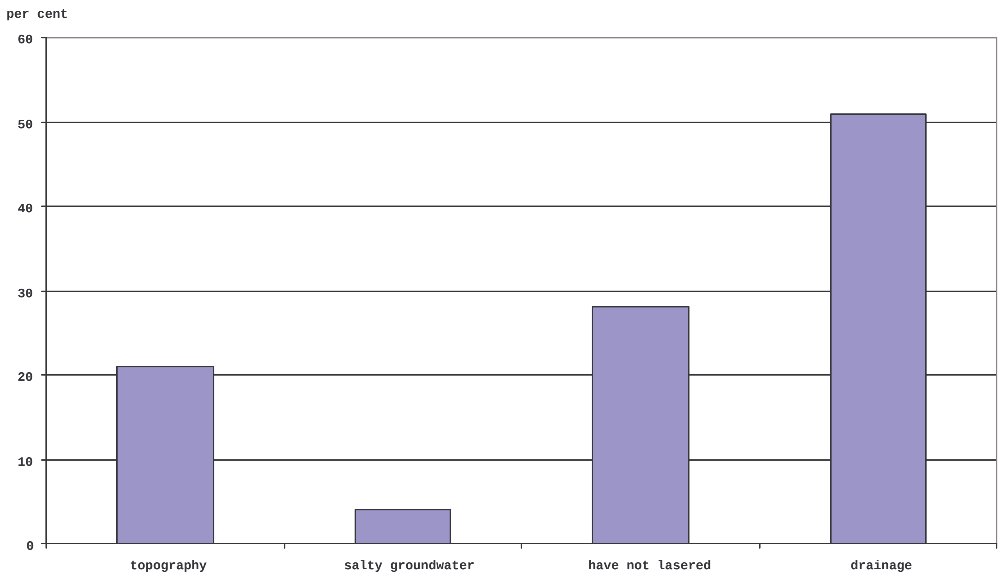

Figure 10: Reasons for not having a recycling dam

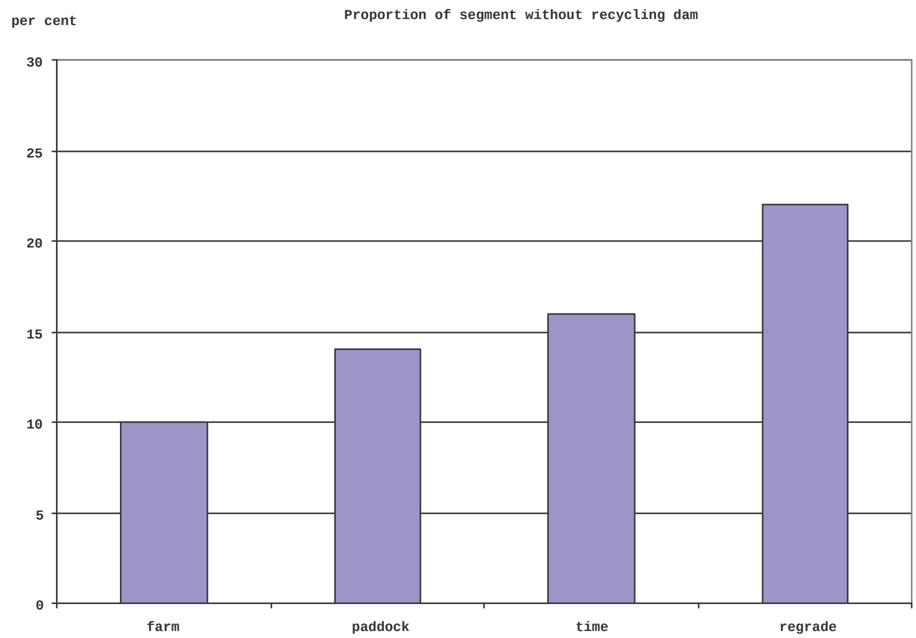

Figure 11: Farms without recycling dams by laser grading segment

Approximately 38 per cent of farmers installed their dams to be able to irrigate on demand. The pattern of association between the laser grading segments and the recycling dam segments seems consistent with the labour and water constraints that characterise both sets of segments.

Groundwater irrigation

Approximately 36 per cent of dairy farmers irrigate with groundwater. Almost all of these farmers have installed their own groundwater pump (96 per cent). The remaining four per cent irrigate with groundwater from a community pump. Approximately 80 per cent of farmers who irrigate with groundwater have to shandy their water.

Interviews with farmers in the first stage of the study revealed that the main reasons for installing groundwater pumps are to boost supplies of irrigation water, to alleviate problems with a high watertables, and to increase control over the timing of irrigations (irrigating on demand). In figure 12 the proportion of farmers in the sample who installed a groundwater pump for these reasons is presented. The figure shows that a high proportion of farmers installed pumps to manage high watertables or to enable farmers to irrigate on demand, as well as to boost irrigation supplies.

We found that farmers who reported a problem with high water tables, saline groundwater or insufficient water right were more likely to irrigate with groundwater than were other farmers.[11] For example, 50 per cent of farmers who have a problem with high water tables irrigate with groundwater compared to 31 per cent of farmers who do not have this problem. Similarly, 45 per cent of farmers who have a problem with insufficient water right irrigate with groundwater compared to 25 per cent of farmers who do not have this problem. This is consistent with farmers using groundwater to manage water table problems and to augment insufficient irrigation supplies.

In figure 13 the proportion of farmers in each recycling dam segment who have installed a ground water pump and who irrigate with groundwater is presented. We reported earlier that the proportion of farmers in the 'store and demand' and 'store only' segments who irrigate with groundwater is significantly higher than in other segments. The results in figure 13 corroborate this finding with the proportion of farmers installing groundwater pumps in the 'store and demand' and 'store only' segments being significantly higher than in other segments.[12]

In figure 14 the pattern of reasons for installing groundwater pumps across the recycling segments is shown. The proportion of farmers in the 'store and demand' and 'demand only' segments who gave being able to irrigate on demand as a reason for installing a groundwater pump is significantly higher than in other segments.[13] The proportion of farmers in the 'store and demand' segment who gave controlling a high water table as a reason for installing a groundwater pump is significantly higher than in other segments.[14] In contrast the proportion of farmers in the 'other' segment who

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[11] For high water tables χ^2=22.0, p=0.00, for saline groundwater χ^2=5.9, p=0.01, for insufficient groundwater χ^2=28.8, p=0.00.
[12] For installation of groundwater pumps χ^2=27.1, p=0.00.
[13] For irrigate on demand χ^2=16.0, p=0.00.
[14] For controlling high watertables χ^2=9.0, p=0.05.

gave controlling a high water table as a reason for installing a groundwater pump is significantly lower than in other segments.

Note that the proportion of farmers who gave boosting irrigation supply as a reason for installing a groundwater pump is similar across the recycling dam segments.

In conclusion, these results indicate that a high proportion of groundwater pumps are installed to help farmers manage high watertables or to enable farmers to irrigate on demand, as well as to boost irrigation supplies. On the whole, the installation of groundwater pumps seems consistent with the findings from the analysis of recycling dams in two ways. First, because farmers who installed recycling dams to store irrigation water are more likely than other farmers to install groundwater pumps. Second, because farmers who installed recycling dams to irrigate on demand are likely to install groundwater pumps for the same reason.

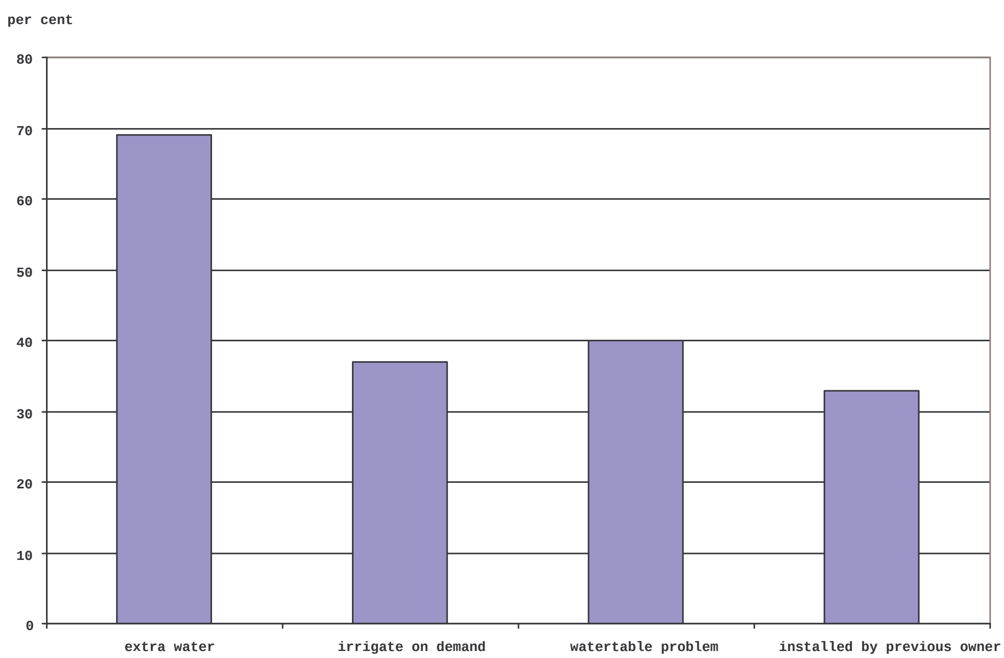

Figure 12: Reasons for installing a groundwater pump

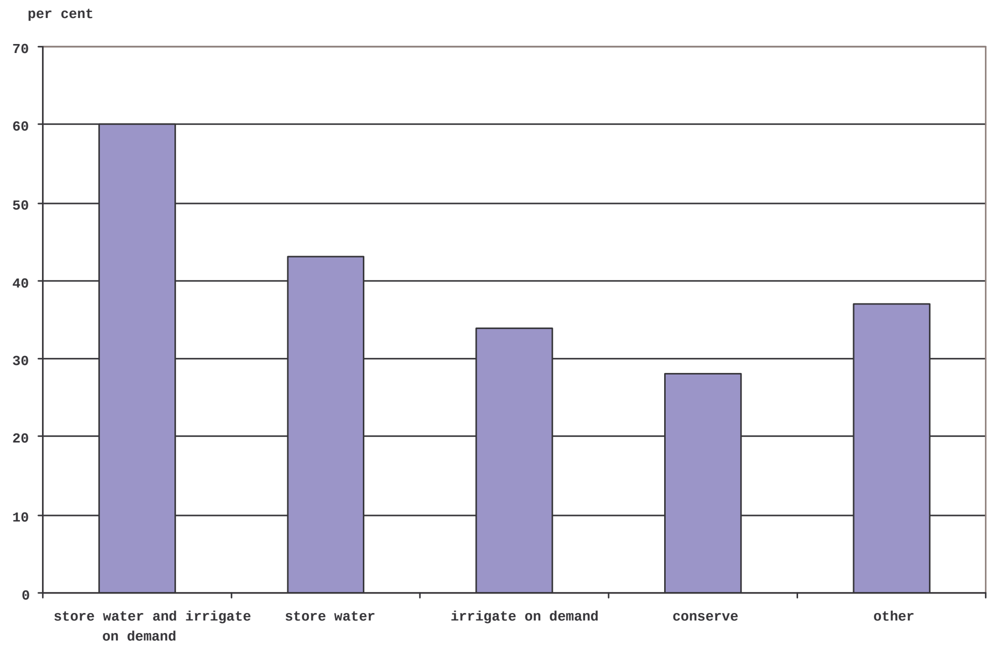

Figure 13: Groundwater pumps and irrigation by recycling dam segment

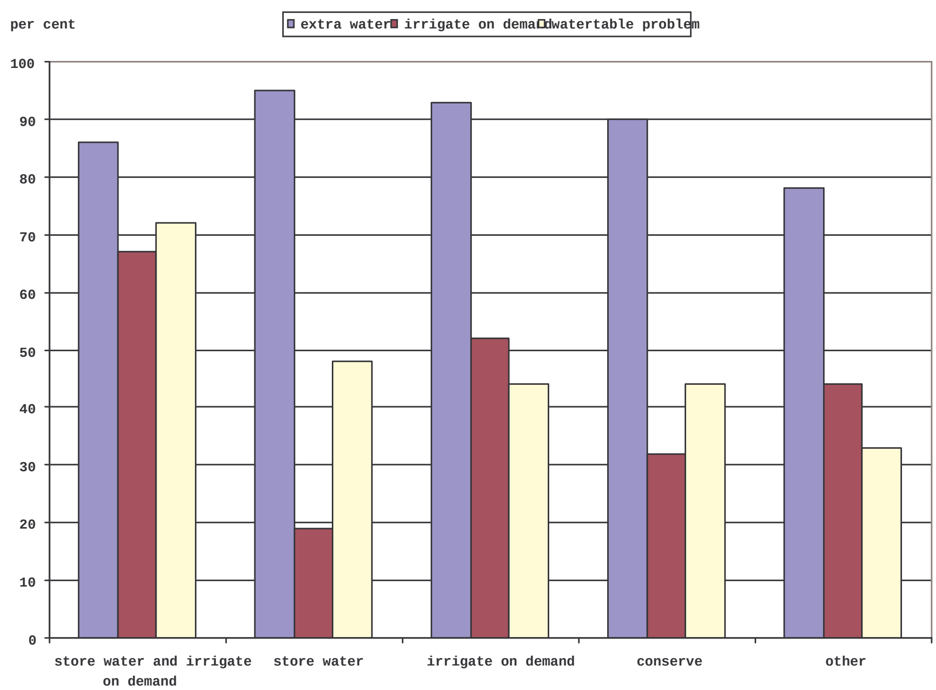

Figure 14: Reasons for installing groundwater pumps by recycling dam segment

Water babies

In the first stage of this study, farmers explained that they use water babies for two main reasons. To check or monitor irrigations when the task of monitoring is unusually inconvenient for the farmer, and to monitor irrigations when extra care is required to avoid the risk of major water loss on lasered irrigation bays that do not drain to a recycling dam. Checking irrigations can be a particularly inconvenient and irksome task when it is regularly required late at night.

Approximately 22 per cent of the farmers in our sample use water babies. In figure 15 the reasons for using a water baby are graphed. The figure shows that most farmers use water babies as an alarm when they are irrigating at night.

We found farmers with a section of their properties that did not drain to a recycling dam were significantly more likely to use a water baby than other farmers. They were also significantly more likely to nominate using the water baby as a check on lasered bays that do not drain to a recycling dam.[15]

We found that farmers with a problem with high water tables and saline groundwater were significantly more likely than other farmers to use water babies than other farmers. For example, approximately 30 per cent of farmers with saline groundwater use water babies compared to 19 per cent of farmers without this problem.[16] This suggests that part of the motivation for farmers to use water babies is to reduce water use and accessions to groundwater tables by monitoring water flow over irrigation bays.

No other significant relationships were found relating to the use of water babies.

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[15] For using a water baby $\chi^2=14.7$, $p=0.00$, for nominating as a check on bays not draining to a recycling dam $\chi^2=17.8$, $p=0.00$.
[16] For high water tables $\chi^2=7.9$, $p=0.00$, for saline groundwater $\chi^2=9.9$, $p=0.00$.

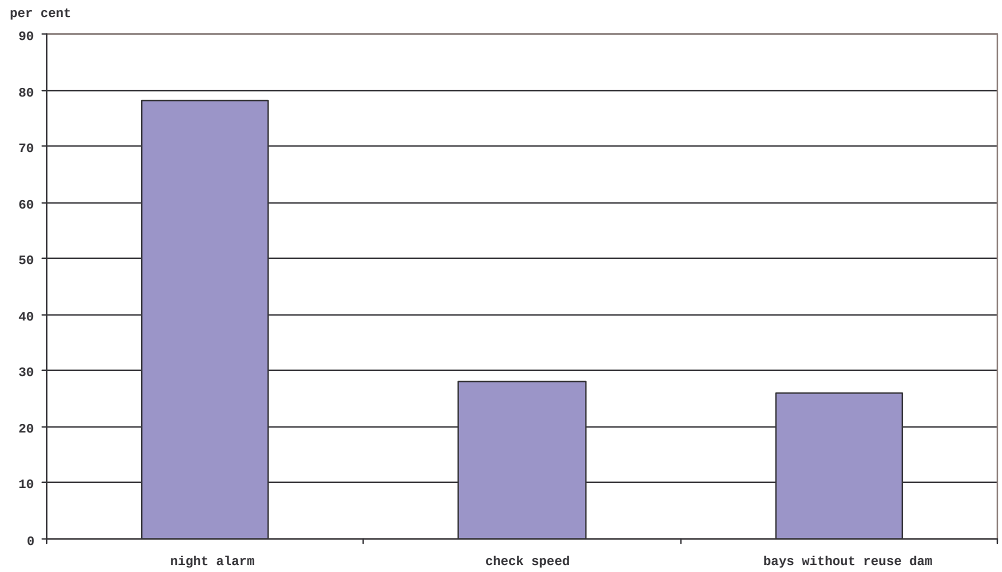

Figure 15: Reasons for using water babies

Automatic irrigation

Approximately 10 per cent of the farmers in the sample have installed automatic irrigation. During interviews farmers explained the major benefits of automated irrigation systems are savings in the time and effort that has to be devoted to irrigation. In figure 16 reasons for installing automatic irrigation are presented. The results show the main reason for installing automatic irrigation is to save time irrigating, especially at night. This is consistent with the results of other studies (Maskey 1996; Maskey 1998).

The proportion of farmers in each laser grading segment that had adopted automatic irrigation was not significantly different.[17] However, farmers in all segments except the 'selective regrading' segment had laser graded to save time. This suggests the proportion of farmers in the 'selective regrading' segment that had adopted automatic irrigation should be significantly lower than in other segments. This was the case

[17] For adopting automatic irrigation χ^2=6.3, p=0.09.

with seven per cent of farmers in the 'selective regrading' segment using automatic irrigation compared to 12 per cent in the other segments.[18]

Approximately 25 per cent of farmers who do not have automatic irrigation reported they are planning to install it. The reasons they gave for planning to automate mirror those of farmers who have already automated (see figure 17).

The proportion of farmers in each laser grading segment that are planning to adopt automatic irrigation is significantly different.[19] An examination of figure 18 shows that a high proportion of farmers in the 'farm redevelopment' segment in particular are planning to install automatic irrigation. The proportion of farmers in each recycling dam segment that are planning to adopt automatic irrigation is also significantly different.[20] An examination of figure 19 shows that a higher proportion of farmers in the 'store and demand', 'demand only' and 'store only' segments are planning to install automatic irrigation.

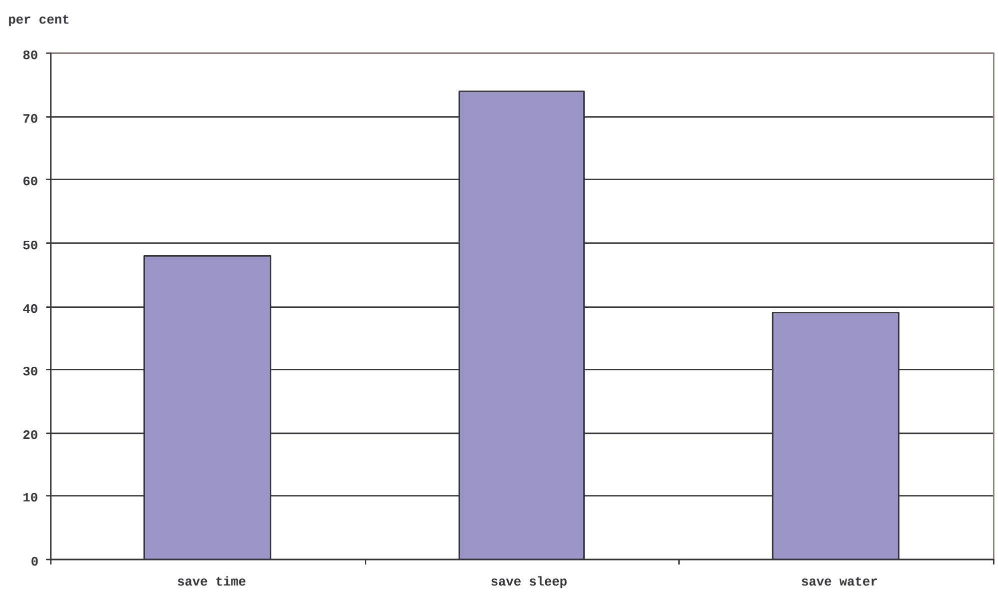

Figure 16: Reasons for installing automatic irrigation

[18] χ^2=5.4, p=0.02.
[19] For adopting automatic irrigation χ^2=35.3, p=0.00.
[20] For adopting automatic irrigation χ^2=16.7, p=0.00.

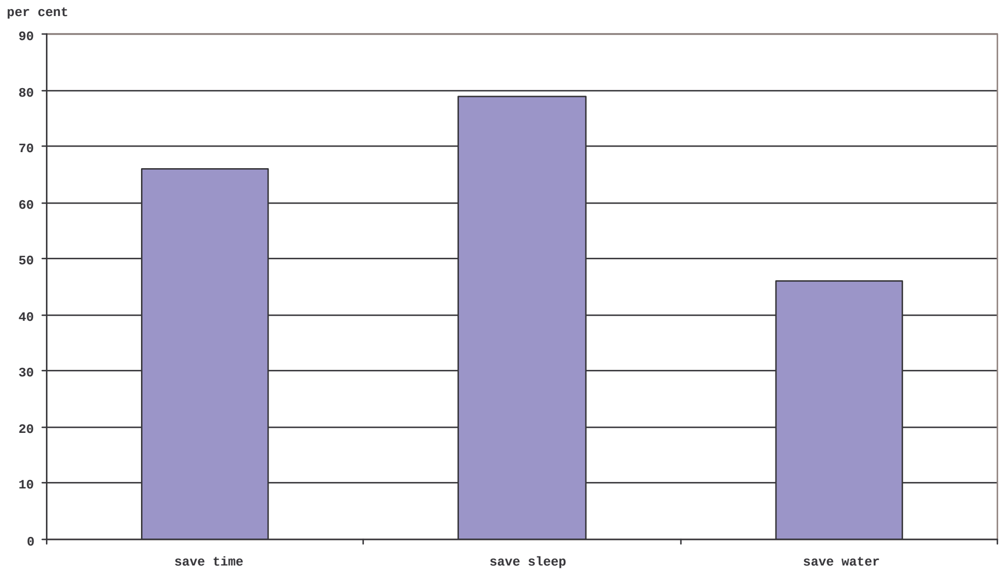

Figure 17: Reasons for planning to install automatic irrigation

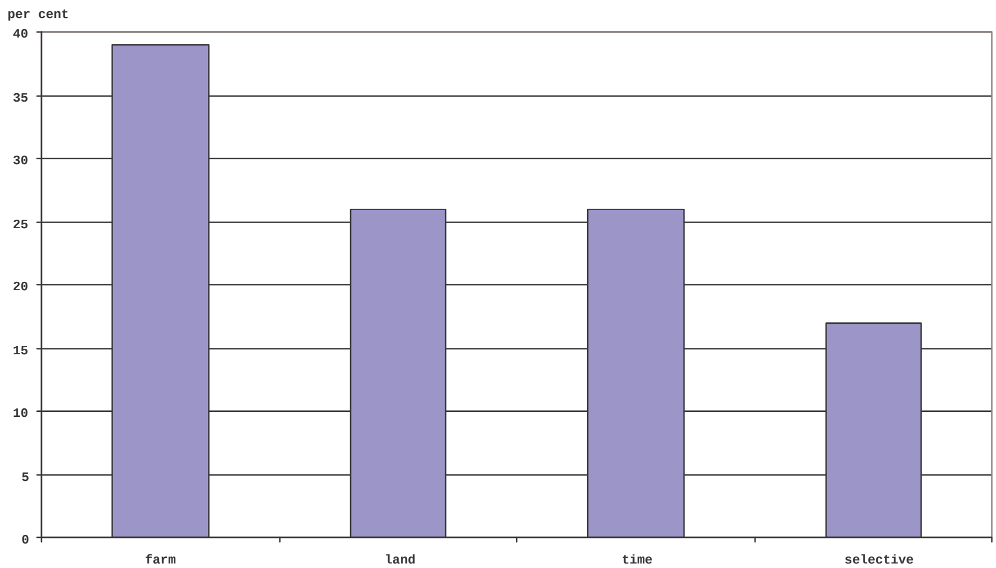

Figure 18: Plans to install automatic irrigation by laser grading segment

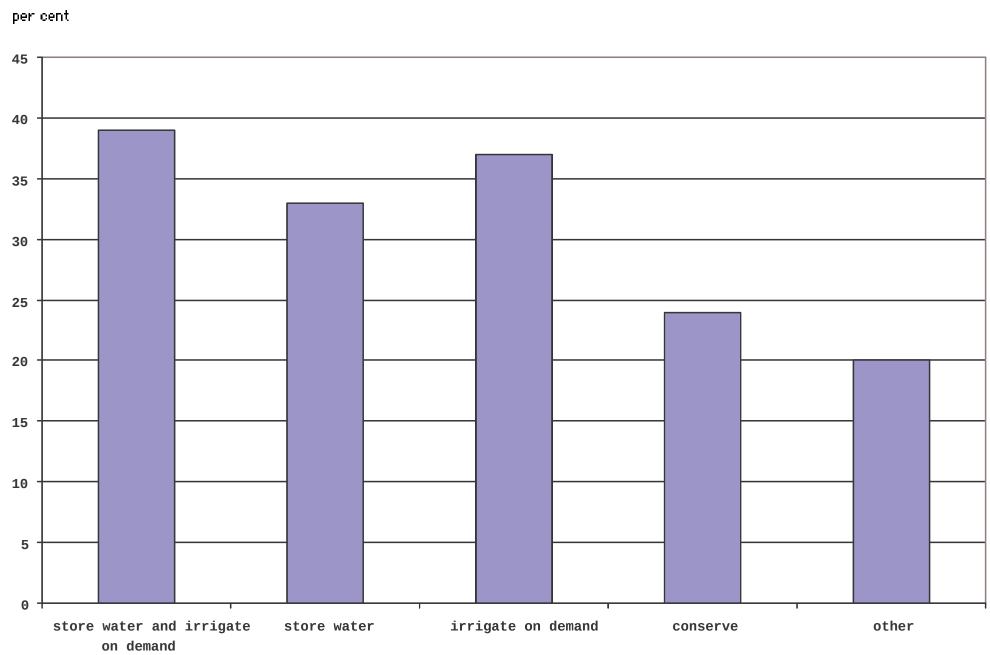

Figure 19: Plans to install automatic irrigation by recycling dam segment

Farmers who are planning to install automatic irrigation have significantly larger areas to irrigate (home farm and out block) than other farmers (159 hectare on average compared to 112 hectares).[21]

The results reported here suggest that the main reason for adopting automatic irrigation is to avoid regularly irrigating at night. They also suggest, however, that a combination of factors force farmers into irrigating at night and that these factors may be changing over time. Consequently, some form of multi-variate analysis is required to identify the factors that influence the adoption of automatic irrigation. We used discriminant analysis for this purpose (Tabachnik and Fidell 1989). The detailed results are available on request from the authors.

First, we used discriminant analysis to identify the factors that were associated with those farmers who had already adopted automatic irrigation. We included a range of factors in the analysis such as the area irrigated on the home farm and out blocks, the number of irrigation wheels that must be managed, and the amount of labour available for irrigating and milking.

[21] $F_{1, 508}$=19.9, p=0.00

We found the adoption of automatic irrigation was associated with smaller area irrigated per irrigation wheel, smaller area irrigated per person irrigating, less hours irrigating per day but more days irrigating per week and a relatively large area of irrigation on the out block. We found plans to adopt automatic irrigation were associated with having a larger property to irrigate, larger area irrigated per person irrigating, and more days irrigating per week. These results suggest that, in the past, the adoption of automatic irrigation was influenced more by farm and irrigation layout than farm size whereas adoption is now mostly influenced by farm size.

Finally, we found that farmers who have automated or plan to automate are more likely to use water babies than other farmers. Approximately 20 per cent of farmers with water babies have automated their irrigation while approximately 40 per cent of farmers with water babies plan to automate their irrigation. This is consistent with the fact that saving time irrigating at night is a primary motivation for adopting both of these technologies and suggests that, in many cases, the use of water babies is a precursor to adopting automatic irrigation.[22]

Irrigation scheduling using evaporation information and soil moisture monitoring

Most dairy farmers start the first irrigation of a season on the basis of their experience and subjective assessments of the dryness of the soil (see figure 20). Virtually all farmers schedule their irrigations during the season either on a fixed rotation, on the basis of their experience, or by a combination of these criteria (see figure 21).

Although 14 per cent of farmers have tried using evaporation information or soil moisture monitoring, only nine per cent of farmers actually use evaporation information to help them schedule their first irrigation of the season or to schedule irrigations during the season. Less than one per cent of dairy farmers in the sample have tried using soil moisture monitoring for irrigation scheduling.

In figure 22 the experiences of farmers who have tried using evaporation information or soil moisture monitoring to help them schedule irrigations are presented. Approximately 50 per cent of the farmers who have tried using these scheduling

[22] For adopting automatic irrigation and using a water baby χ^2=23.2, p=0.00, for planning to adopt automatic irrigation and using a water baby χ^2=24.8, p=0.00.

practices are likely to say their use of them was constrained because of their grazing rotation or because they have to order water in advance. About 40 per cent of farmers described these practices as matching their experience. Only 15 per cent of farmers described these practices as working well.

We found that farmers are more likely to try to use evaporation information or soil moisture monitoring if they have problems with high water tables and saline groundwater, or problems with unreliable channel supplies. Farmers who have automated their irrigation or who use water babies are also more likely than other

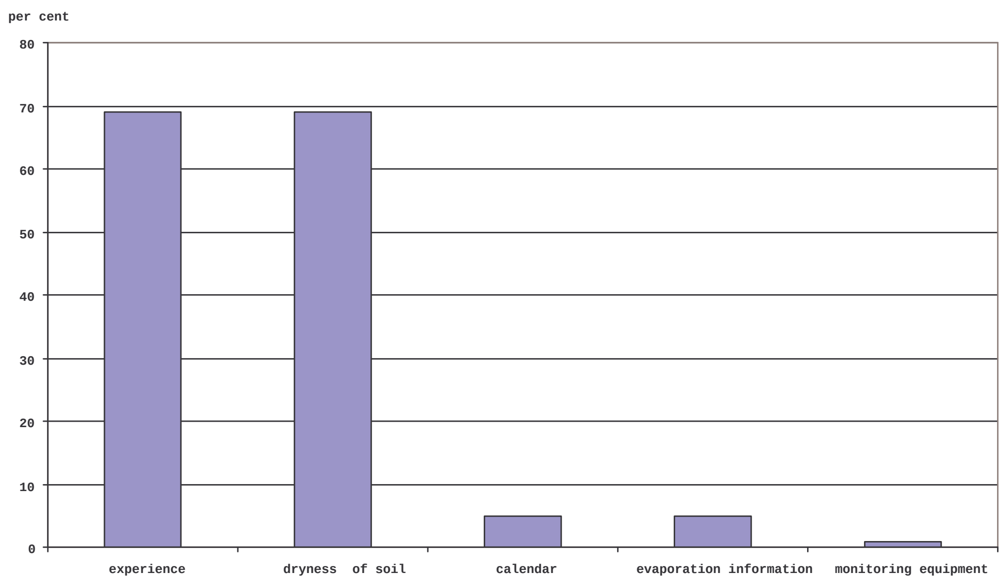

Figure 20: Scheduling irrigations at the start of the season

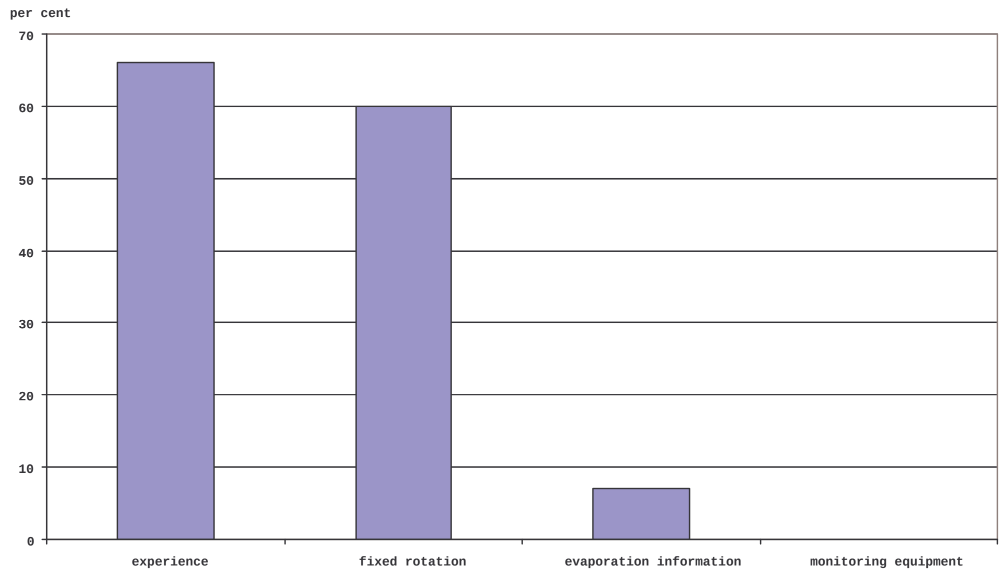

Figure 21: Scheduling irrigations during the season

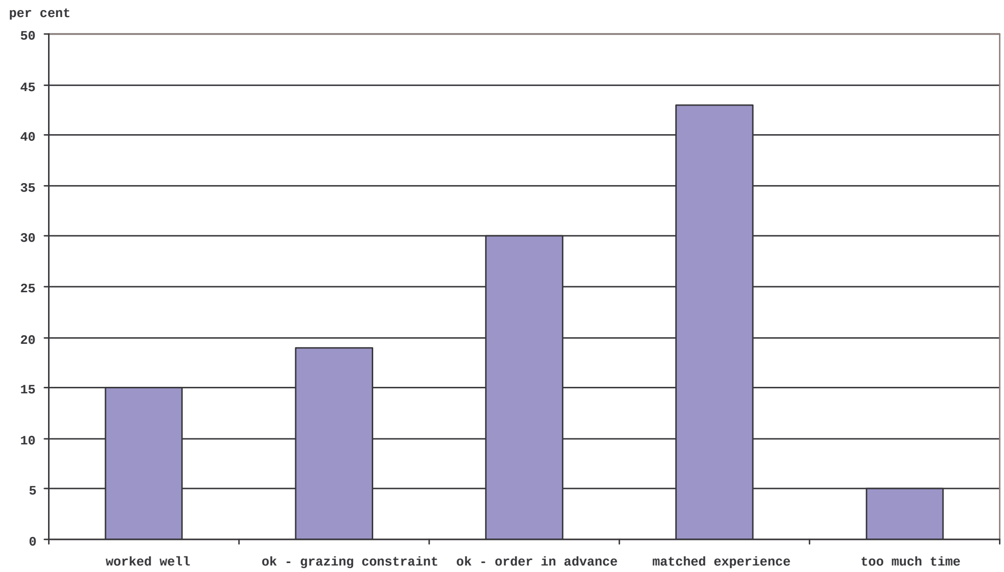

Figure 22: Experiences with evaporation data and soil moisture monitoring

farmers to try to use evaporation information or soil moisture monitoring.[23] These results suggest that the primary motivation to try using evaporation information and soil moisture monitoring to schedule irrigations is to reduce water use.

We found that the farmers who are most likely to continue using evaporation information or soil moisture monitoring are those who have problems with high water tables and saline groundwater. Farmers who have automated their irrigation are more likely than other farmers to discontinue using evaporation information or soil moisture monitoring.[24] These results suggest that these scheduling practices may not be especially worthwhile for automated irrigation systems but offer considerable benefits for those farmers having problems with saline groundwater.

The adoption of spray irrigation

Only two per cent of dairy farmers in the sample had adopted spray irrigation. The main reason for installing spray irrigation is to irrigate country that is either too hilly or too sandy for flood irrigation.

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[23] For high water tables χ^2=11.5, p=0.00, for saline groundwater χ^2=18.3, p=0.00, for unreliable channel supplies χ^2=11.2, p=0.00, for automatic irrigation χ^2=34.3, p=0.00, for water babies χ^2=17.3, p=0.00.

[24] For high water tables χ^2=3.4, p=0.06, for saline groundwater χ^2=4.0, p=0.05, for automatic irrigation χ^2=10.1, p=0.00.

Conclusion

Interviews with farmers in the first stage of this project suggested that saving time is the major concern of dairy farmers. The results of the survey conducted in this second stage of the project support that finding. Saving time was identified as a major factor in the adoption of laser grading and the installation of recycling dams (as being able to irrigate on demand). Saving time, especially at night, was identified as the factor influencing the adoption of water babies and automatic irrigation.

Managing high water tables and saline groundwater was identified as a factor in laser grading and the installation of recycling dams, and irrigating with groundwater. It also appears the successful use of evaporation information and soil moisture monitoring occurs where the use of these techniques is motivated by a need to manage high water tables and saline groundwater.

Saving water was identified as a factor in the adoption of laser grading, especially among those farmers whose production had been limited by poor farm layout and the presence of humps and hollows in irrigation bays. Saving water was also identified as the major factor in the adoption of groundwater irrigation. Saving water was a factor in the adoption of recycling dams, especially when dams formed an integral part of a groundwater irrigation system. However, saving water did not appear to be a major factor in the adoption of water babies or automatic irrigation. Saving water also did not appear to be a factor *per se* in the adoption of evaporation information or soil moisture monitoring for irrigation scheduling.

A substantial proportion of the dairy farmers in the sample do feel their water right is insufficient, nearly 50 per cent. However, given that most farmers have laser graded the majority of their properties and that most farmers have also installed recycling dams, the potential to influence water use efficiency by decreasing water use on farm seems limited. Farmers do not view the use of water babies, automatic irrigation or irrigation scheduling using evaporation information or soil moisture monitoring as contributing greatly to increasing water use efficiency.

These findings mean that, apart from irrigating with groundwater, the potential for farmers to respond to any decline in the availability of irrigation water by changing irrigation practices is limited. This suggests, in our view, the only possible actions farmers might take in responding to limited water supplies would be to purchase additional water or to increase their use of fertiliser and purchased feed supplements (such as grains and concentrates). While these actions would increase water use efficiency, they would not reduce water use *per se*.

The scope for increasing water use efficiency by improving the management of irrigation also seems limited. The combination of laser grading and recycling dams is far less demanding of management expertise than the traditional, labour intensive irrigation layouts of narrow bays and small bore outlets. The high rate of adoption of this combination of practices means that, over time, the influence of irrigation management on variations in water use per hectare will become less and less important. Such variations will increasingly reflect differences in contextual factors between farms such as soil type and farm topography.

This suggests that variations in water use per hectare should be small relative to variations in water use efficiency, and that variations in water use efficiency should be related to the management of pastures, fertiliser and supplementary feeding technologies. Note that (Armstrong, Knee et al. 1998) found the majority of farmers were not applying significantly more water than was necessary. Their results also indicated that variations in use efficiency were not related to variations in water use per hectare but were related to fertiliser use and supplementary feeding.

We concluded from these results that efforts to improve water use efficiency should be directed toward pasture management, fertiliser management and management of supplementary feeding rather than irrigation management. Hence, the survey results reinforce the conclusion reached in the first stage of this project that:

> *'improvements in water use efficiency stem mainly from changes in pasture, fertiliser, fodder production and supplementary feeding practices (water*
>
> *augmenting technological change) and not from reduced water use. This implies that research and extension efforts to increase water use efficiency*

> *should concentrate on the development and adoption of water augmenting practices rather than attempting to reduce water use by focusing on irrigation practice and management.'*

The high level of adoption of laser grading and recycling dams suggests there is little reason to allocate extension resources to promoting these practices. There also seems to be little reason to direct extension resources to promoting the use of groundwater for irrigation. Irrigating with groundwater is motivated either by a problem with too much water (high watertables and salinity) or a problem with too little water (insufficient water right). Consequently, the adoption of groundwater irrigation is prompted by environmental factors (policy and biophysical). Hence the adoption of groundwater irrigation is unlikely to be influenced by extension activities when these factors are absent.

There is little reason to direct extension resources to promoting the use of spray irrigation unless significant savings can be demonstrated in the time farmers would need to spend irrigating. However, if spray irrigation is shown to generate substantial savings in water use it might be promoted to dairy farmers concerned about insufficient water right, especially those without access to groundwater suitable for irrigation.

There appears to be potential for extension activities to promote the adoption of water babies and automatic irrigation. With respect to water babies, activities promoting their use on lasered bays that do not empty into recycling dams or some form of drain should be considered. More importantly, extension activities promoting the use of water babies as a means of saving time, especially when irrigating at night, should be considered. There is some evidence that the adoption of water babies is a precursor to the adoption of automatic irrigation. This suggests activities promoting water babies could be targeted at potential adopters of automatic irrigation.

With respect to automatic irrigation, extension activities promoting the use of automatic irrigation as a means of saving time, especially among farmers who have to irrigate at night, should be considered. Of the farmers who irrigate at night, those with large dairy properties and who use water babies, could be targeted as being the most likely to adopt automatic irrigation.

Extension activities aimed at promoting the use of evaporation data or soil moisture monitoring to assist irrigation scheduling should be targeted at farmers who have problems with high water tables or salinity, especially those who are able to irrigate on demand.

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Appendix A

Interview Questionnaire