Soil Monitoring, Irrigation Scheduling and Fruit Production

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Executive Summary

Methods for scheduling irrigation by objectively monitoring soil moisture have been developed in recent years. There is a concern that the rate of adoption of these methods is too slow. The purpose of this study was to identify the factors influencing adoption of objective soil monitoring by stone and pome fruit growers.

In-depth personal interviews were conducted with approximately thirty growers to identify the key factors influencing the adoption of strategies for managing waterlogging. Growers from the Shepparton, Cobram, Swan Hill, Tumut and Batlow districts were interviewed.

During interviews with fruit growers we found that the installation of micro-irrigation was a major factor affecting the use of objective monitoring of soil moisture for irrigation scheduling. Consequently, we have concentrated first on describing the factors influencing the adoption of micro-irrigation. We found growers adopt micro-irrigation to either save water to manage a salinity or water table problem, to save labour and time, or to increase control over the timing or application of watering. We found some growers around Batlow and Tumut have adopted micro-irrigation to save water because of limited supplies.

We found that growers who have installed micro-irrigation are unlikely to adopt monitoring unless it is demonstrated to be more accurate than their experience and easy to use.

Most growers are in a position to use soil moisture monitoring (such as tensiometers) to assist them in deciding when to commence the irrigation season. Most growers may also be able to use monitoring to assist them to optimise their irrigation management in terms of irrigation frequency and run-times. However, as a general rule, growers are too constrained by access to water, the cost of power and the scheduling of other farm activities to use monitoring to directly schedule irrigations during the season. Only growers who have access to permanently available water (growers at Swan Hill or growers with on-farm storage at Tumut or Batlow for example) are in a position to use monitoring to schedule irrigations throughout the season.

Acknowledgments

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We are indebted to the fruit growers 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

More precise methods for scheduling irrigation have been developed in recent years. Basically, these methods involve scheduling the timing and length of irrigation by objectively monitoring soil moisture. The major force driving the development of these methods has been the concern of organisations involved in natural resource management to increase the efficiency of irrigation in the fruit growing industries (Meissner 1998), (Boland 1997).

Currently, best management practices are being identified for stone and pome fruit (Meissner 1998), Boland 1998). These practices will cover irrigation scheduling as well as nutrient management, salinity control and vigour management. The objective monitoring of soil moisture is seen to be critical to the successful adoption of these best management practices (Boland 1998). While the technology to objectively monitor soil moisture has been available for some years, only a minority of fruit growers are using the technology (Boland 1998). Most growers continue to rely on subjective assessments of soil moisture and their experience to schedule irrigations.

Our objective in this study was to identify the factors influencing the adoption by fruit growers of irrigation scheduling based on objective monitoring of soil moisture.

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 careful planning and management.

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 ignorance,

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 likely to meet with limited success. Fourth, the notion that farmers can be categorised according to their propensity to innovate is not consistent with this perspective.

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 (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 employed:

- 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 and Sandall 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.

In terms of objective methods for scheduling irrigation, understanding the adoption of these methods involves the following. First, identifying the technologies, practices and resources at the farm level that influence the benefits and costs of adopting such methods. This involves interviews with farmers, extension staff and other relevant experts or specialists. Second, classifying fruit growers 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 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 not adopted. 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.

Irrigation systems and scheduling

The adoption of new scheduling methods will depend on the benefits these methods offer the fruit grower. In our interviews with fruit growers it quickly became apparent that the benefits of new scheduling methods depend on:

- The need to conserve irrigation water,
- The type of irrigation system used by the fruit grower,
- The planting techniques used by the grower, and
- The land and labour resources available to the farm enterprise.

The availability of irrigation water had not restricted the production of fruit growers we interviewed in the Shepparton, Cobram and Swan Hill districts. These growers regularly receive allocations in excess of requirements. These growers did not mention the price of irrigation water as a reason for conserving water. This means that growers in these districts will only need to conserve irrigation water if:

- They are experiencing natural resource problems (such as high water tables, soil or water salinity) which can be influenced by irrigation management, or
- They are experiencing problems with the delivery of irrigation water to the property because of the design of the irrigation distribution system.

On the other hand, the availability of water does restrict the production of some growers around Tumut and Batlow. These growers do attempt to conserve irrigation water to maximise production.

The type of irrigation system used by the fruit grower directly influences the ability of the grower to vary the timing and length of irrigations. Basically, growers with flood irrigation have little opportunity to vary their irrigation routine, especially once picking has commenced.

Growers must simultaneously manage a number of key farm enterprise activities including spraying, picking, grading, and marketing in conjunction with irrigation. This places a premium on the grower's time. Typically, fruit blocks take between six and ten hours to flood irrigate. Consequently, growers with flood irrigation will endeavour to concurrently irrigate as many fruit blocks as possible to reduce the amount of time spent irrigating. Blocks must also be given two or three days to dry out after irrigating before spraying or picking can commence. The result is that, on farms with flood irrigation, operations such as spraying and picking are undertaken during the week and irrigation carried out on weekends (with all blocks on the farm being irrigated). This means that growers with flood irrigation have little opportunity to vary their irrigation routine.

Growers with impact sprinkler (under tree knocker sprinkler) irrigation have more flexibility than growers with flood irrigation, but are not as flexible as growers with micro-irrigation. On one hand, growers with impact sprinkler irrigation water the entire block. Consequently, irrigated blocks must be left to dry out before activities such as spraying and picking can be undertaken. On the other hand, growers with impact sprinkler irrigation are able to vary their irrigation routine. Impact systems are pressurised, controlled flow systems. Consequently, there is no need to continuously monitor each block while irrigating and the water delivered to each block can be controlled by varying the irrigation period. This means that growers with impact sprinkler irrigation have the potential to irrigate blocks sequentially and to 'customise' the irrigation of each block. This means irrigation on one block need not interfere with activities such as spraying and picking on another block.

The extent to which the potential benefits of impact sprinkler irrigation can be realised depends on the reliability of the irrigation distribution system. Growers serviced by 'spur' channels, for example, may experience difficulties obtaining continuous access to moderate volumes of water over a sustained period (compared to micro-irrigation requirements). In these circumstances growers with impact sprinkler irrigation may be forced to operate in a fashion similar to growers with flood irrigation (ie ordering large volumes and irrigating blocks concurrently to complete irrigation as rapidly as possible). Problems with the reliability of the distribution system may be managed by installing a micro-irrigation system.

Impact sprinkler irrigation offers the flexibility to irrigate without severely constraining other farm activities and to 'customise' the irrigation of a fruit block. Fruit growers with these irrigation systems do have the potential to schedule irrigation using objective monitoring of soil moisture.

In contrast to growers with flood irrigation, growers with micro-irrigation are able to vary their irrigation routine. Irrigation water is delivered directly to the base of the fruit tree by micro-irrigation systems. This means less water is required to irrigate a block of trees. It also means that, as blocks are not flooded, other activities such as spraying and picking can be undertaken concurrently with irrigation. Micro-irrigation systems are pressurised, controlled flow systems. As a result, there is no need to continuously monitor each block while irrigating and the water delivered to each block can be controlled by varying the irrigation period. This means that growers with micro-irrigation have the flexibility to irrigate blocks sequentially and to 'customise' the irrigation of each block.

The capacity to customise irrigation means that growers can use micro-irrigation to overcome watering problems in blocks composed of a range of soil types. Also, as water is delivered directly to the base of the fruit tree by micro-irrigation systems these systems may be more effective than flood or impact systems on blocks using closer planting techniques. Closer planting techniques such as the Tatura Trellis involve hilling the soil under trees which prevents flood irrigation, and arranging trees in a trellis formation which prevents irrigation using impact sprinklers. Trees planted using these techniques must be irrigated using micro-irrigation. Micro-irrigation systems are also more effective than flood or impact systems on blocks planted to dwarf rootstock.

In short, micro-irrigation offers four potential benefits:

- Reduced use of water
- Reduced use of labour
- Greater control over the volume of irrigation water applied, and
- Direct application of irrigation water to fruit trees.

Since micro-irrigation offers the flexibility to irrigate without constraining other farm activities and to 'customise' the irrigation of a fruit block, fruit growers with these irrigation systems do have the potential to schedule irrigation using objective monitoring of soil moisture.

In conclusion, the adoption of micro-irrigation (or possibly impact sprinkler irrigation) is a prerequisite for adopting irrigation scheduling based on objective monitoring of soil moisture. If the supply of irrigation water is not constraining production, then growers are most likely to adopt micro-irrigation to reduce water use when they need to manage a watertable or salinity problem, or they are experiencing difficulties with the irrigation delivery system. Otherwise, growers may adopt micro-irrigation to reduce the demands irrigation imposes on labour and to overcome the constraints flood irrigation imposes on the conduct of other activities such as spraying and picking. Growers may also adopt micro-irrigation when adopting closer planting techniques or to overcome watering problems caused by variable soil profiles.

Scheduling and soil moisture monitoring

In our interviews we discovered fruit growers who have micro-irrigation and some experience of monitoring did not believe that scheduling irrigation on the basis of soil moisture monitoring would substantially improve fruit quality or quantity. In other words, they believed fruit trees were not sufficiently sensitive to the timing of irrigations for the differences between scheduling using traditional techniques and scheduling using objective monitoring to be noticeable. As a consequence, growers who have installed spray or micro-irrigation are unlikely to use objective monitoring of soil moisture to schedule irrigation unless:

- Objective monitoring of soil moisture is shown to be more reliable, easier to use and quicker than traditional techniques, and
- There is a continuing need to conserve water to maximise production.
- There is a continuing need to conserve water to manage a watertable or salinity problem.

- There is a continuing need to reduce labour.

The number of monitors that need to be installed in a block, and their arrangement across the block, depends on the variation in soil types within the block. If the soil profile is fairly uniform then the soil moisture across the block can be predicted using only a small number of monitors. Consequently, monitors will be relatively inexpensive to install and taking soil moisture readings will be a simple task. On the other hand, if the soil profile is quite diverse then a large number of monitors will be needed to predict soil moisture in different parts of the block. Consequently, monitors will be relatively expensive to install and taking soil moisture readings will be a time consuming task. Where a block is being redeveloped sub-main design and tap positioning may also influence the siting of monitors.

Monitoring is unlikely to be considered, even where it is practical, unless the installation of micro-irrigation has failed to contain a watertable or salinity problem, or additional labour savings are sought through automatic irrigation. If scheduling using monitoring is not expected to generate an improvement in the quantity or quality of fruit produced then the only potential benefit it may offer is reduced water use or reduced labour use.

Objective monitoring of soil moisture can be used to manage Regulated Deficit Irrigation (RDI). RDI involves reducing the water applied during irrigation to manage vegetative growth. RDI can be undertaken without using objective soil moisture monitoring especially if impact sprinkler or micro-irrigation has been installed (though not, perhaps, with the same degree of precision). Hence, in our opinion growers are unlikely to install soil moisture monitors simply in order to institute RDI. Consider the following example.

> *Robert runs a small flood irrigated orchard in Tresco. He is in the process of getting an irrigation plan for his orchard to convert to micro irrigation. He has some tensiometers that he uses as a back up during the irrigation season. Robert is able to alter his irrigation run time by irrigating alternate rows or by increasing the volume of water from the riser so that is reaches the end of the block more quickly. Early in the season Robert will give a 'half' irrigation in either of these two ways to stress his trees and control vegetative growth. In the middle of the season Robert will give the trees an additional "half irrigation" if the trees need extra water.*

Robert is able to get water pretty much on demand at present. He has to give Goulburn-Murray Water 24 hours notice, but has a standing water order which he renews each month.

As a final point, monitors may be employed as part of an automatic irrigation system. Automatic systems are used to save labour. These systems may also be programmed using a timing system. Monitors are likely to be used where soils are relatively uniform and irrigation water is continuously available.

Market segments for irrigation systems

The discussion in the preceding sections suggests to us that there are five market segments in terms of irrigation technologies (see figure 1). These are:

Flood irrigators

These growers have flood or impact sprinkler irrigation. They do not experience labour shortages during the irrigation season. Often these enterprises are managed by extended families. They are not experiencing problems with rising water tables or soil salinity. These growers may install micro-irrigation when replanting blocks, especially if they are using closer planting techniques.

Fred runs canning fruit orchard in Invergordon. He has various properties spread around the district, the majority under knocker sprinklers. The exception is the newest block that he has put under microjets. This is because he has found that it is easier to start closer planted trees on microjets. He's tried closer planting on his sprinklers and found one tree always gets missed. Fred has experienced problems in converting trees to microjets. On one block of four-year-old trees that he converted two years ago he has had fruit size and vigour problems. New plantings on microjets have been fine.

Fred uses an auger to work out when to begin irrigating at the start of the season. From then on he has a seven-day standing water order, which closes in to a six-day standing order in the middle of the season. With this he can irrigate each of his properties every seven days (or six when fruit is growing rapidly). He needs the sequence to get the water ordered and to get through all the shifts in a week. He is struggling to manage the blocks under microjets because he finds they need water

sooner than six or seven days. To overcome this he has been "topping up" the microjet blocks in between with a smaller irrigation run. He irrigates at night to get cheap rate power, except when he has to check the sprinklers and so turns on the system in the late afternoon.

All of Fred's properties are tile drained so he has no water table or salinity problems.

Growers with flood or impact sprinkler irrigation are severely constrained in terms of the timing of irrigations once the season starts. However, some growers in this segment may experiment with monitoring to help them determine when to begin irrigating at the start of the season.

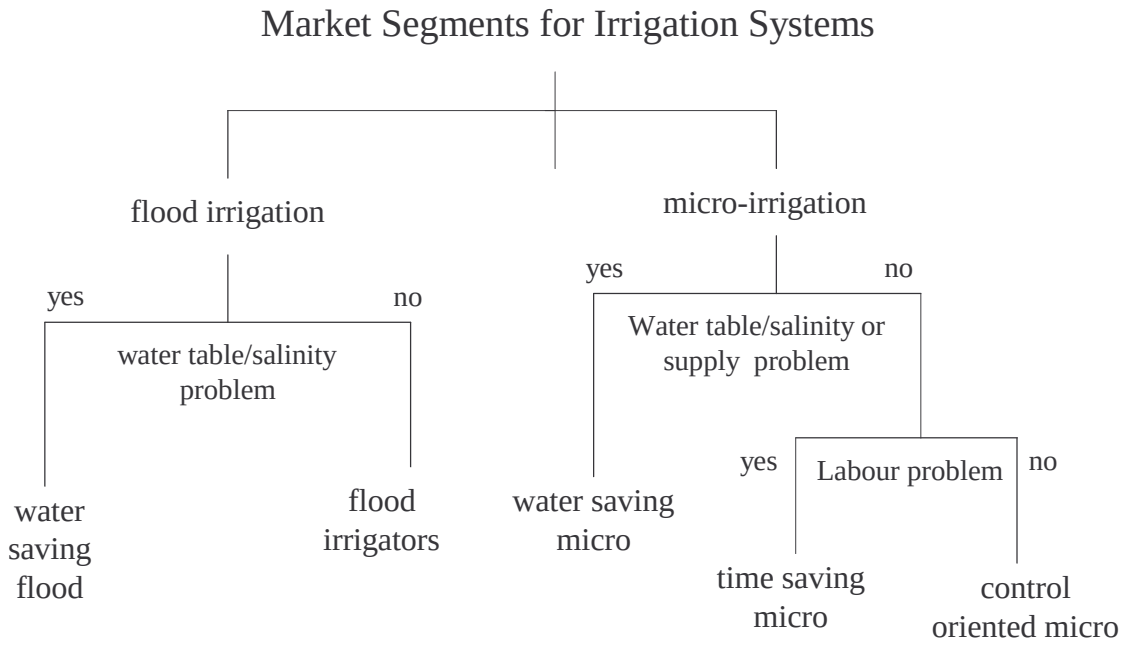
Frank and Tim run a large orchard in Cobram supplying stone fruit and apples for the fresh fruit market and canning. They irrigate with knocker sprinklers. They do have some microjet irrigation on headlands. Frank and Tim have installed four sets of tensiometers (irrometers) that help them to determine when to put on the first irrigation in the season. They also take into account factors such as what the grass looks like and the weather. During the season they irrigate every weekend. This is to juggle the low power tariff, the spraying, and the picking. In the rapid fruit growth stage they irrigate blocks mid week as well.

Although they are on a spur channel and can have problems getting water, Frank and Tim are happy with knocker sprinklers and have no plans to convert to micro-irrigation. Why did they install tensiometers? A Goulburn-Murray Water officer talked them into trying them. They put some in and they are happy with the results. Frank and Tim have no acidity, watertable or salinity problems.

Other fruit growers are in a similar situation.

George and Fiona run a small stone and pome fruit orchard in East Shepparton. Most of the orchard is flood irrigated, with the exception of their new plantings of stone fruit, which they have put under microjets. George has installed two sets of tensiometers in the new plantings that he uses to determine when to irrigate at the start of the season and to use as a check during the season. On the whole he has found that his experience matches the readings he gets from the tensiometers.

Because George uses flood irrigation he has to juggle other orchard management activities like picking and spraying carefully. George tries to irrigate his whole property in one go. George is on a spur channel and can have problems getting the amount of water he needs if the irrigator next door wants to irrigate at the same time.


Market Segments for Irrigation Systems
flood irrigation
micro-irrigation
yes
no
water table/salinity problem
yes
no
Water table/salinity or supply problem
yes
Labour problem
no
water saving flood
flood irrigators
water saving micro
time saving micro
control oriented micro

no

Flood irrigation is not limited to small orchards.

Floyd runs a very large orchard in Ardmona growing apples, pears and stone fruit. Most of the older blocks on the orchard are under knocker sprinklers with newer, closer planted blocks under microjets.

The whole orchard is watered ever five to seven days. Floyd and his irrigator meet every week to plan the next week's schedule. The schedule is recorded for each week and this is used to place a weekly water order with Goulburn-Murray Water. The first irrigation of the season is determined by a check of the soil and the records for last year.

During the season the irrigation schedule is based on experience and other orchard activities (eg the spraying). Floyd had a consulting company put a couple of soil moisture monitor probes in one area as a test or check. From the results they got his experience is correct. He only over-irrigated once during the test period and that was because it rained as well. Floyd doesn't think that spending roughly $3,500 per site for a soil moisture monitoring system would be money well spent.

Floyd has no salt or watertable problems. In the late 1960's some of the trees started showing salinity symptoms. A ground-water pump was installed to reduce the watertable. Many other pumps have gone in around the district and Floyd believes they have contributed to the watertable decreasing over time.

Water saving flood irrigators

These growers are experiencing problems with water delivery, rising water tables or soil salinity. These growers will consider installing micro-irrigation to overcome these problems along with drainage and ground water pumps where necessary.

William and Kate run a fresh market and canning stone fruit orchard. The property is partly irrigated with microjets and partly with knocker sprinklers. William has been converting new plantings to microjets to save water. William and Kate have problems with water delivery – the channel they are on used to have seven wheels on it, now it has 20. William has a standing order for water each weekend but in the middle of the season cannot be guaranteed water on a Friday night. Sometimes he may have to wait until Sunday afternoon. "Sprinklers take a lot more water and we want to concentrate on the tree not the whole [orchard] area". William uses a shovel to test the soil to work out when to put the first irrigation of the season on. Once into the season William irrigates on weekends with a top-up mid week to take advantage of lower power tariffs.

High watertables and salinity have not been a problem for William and Kate – they have a shallow bore that keeps the watertable down.

Time saving micro-irrigators

These growers have installed micro-irrigation to overcome labour shortages they experienced using flood irrigation. They are not experiencing problems with rising water tables or soil salinity. These growers may have experienced production problems when establishing micro-irrigation under fruit trees in mature blocks. These growers may experiment with monitoring but are unlikely to use monitoring on a large scale to schedule irrigations unless it is clearly demonstrated to be more accurate than conventional scheduling methods, and to require little time or labour. Like growers with flood or impact sprinkler irrigation some growers in this segment may experiment with monitoring in determining when to begin irrigating at the start of the season. When demands on labour and time are especially severe growers in this segment may automate their irrigation systems.

Terry runs an orchard growing stone fruit, apples and citrus, all of which are under micro-irrigation. He has been having problems with some trees getting too much water and others being water stressed. He discovered there were large pressure variations across his orchard. Over winter he has been installing pressure regulators so each block can be irrigated for the same amount of time. He has also put in valves and wires so that he can hook his irrigation system up to a computer and automate his system. He sees this as a major labour saving. Terry explained that at 8 am when irrigation shifts need to be checked and turned off he is needed in the shed. He has to organise pickers and also coordinate the transports. He can set the computerised system to take advantage of low power tariffs, save water and save his labour.

Terry has a standing water order, irrigating on weekends with a top up mid week when the fruit are growing rapidly. He has thought about soil moisture monitoring but is concerned that he has too many soil types across his property to make it worthwhile.

Next season Terry is setting up a trial in collaboration with a tree-training consultant. They are going to plant Packham pears on Cobram loam, something not normally done because of excessive vigour problems. They believe they will get better skin finish on the pears because they will be on better soil and they hope to control vigour with water management.

Other fruit growers are in a similar situation.

Tony and Tina run a medium sized orchard in Ardmona, growing stone and pome fruit for the fresh fruit market and for canning. They have converted their entire property to micro-irrigation over a number of years. Tony and Tina said that labour was the major factor in their decision to convert to micro irrigation. They employ extra labour as needed but are keen to keep labour costs to a minimum.

Tony has tried both tensiometers and a gopher to monitor soil moisture. However Tony found these instruments were of limited use. Tony does not have the time in the middle of the season to run around and read the instruments. He has also had problems calibrating the gopher. Tony and Tina thought that an irrigation service similar to the scouting service for pests would be useful for growers like themselves.

Water saving micro-irrigators

Growers in this segment around Shepparton, Cobram and Swan Hill have installed micro-irrigation either to overcome problems with rising water tables or soil salinity. They may have also experienced labour shortages using flood irrigation. These growers may experiment with monitoring but are unlikely to rely primarily on monitoring to schedule irrigations unless it is clearly demonstrated to be more accurate than conventional scheduling methods. Some growers in this segment may experiment with monitoring in determining when to begin irrigating at the start of the season.

Wal and Anna run a small fresh and canning fruit orchard in East Shepparton. They have a severe watertable problem. They have no suitable sites for a ground water pump and do not have any tile drains. Over the last few years they have gradually converted the half of their property that is badly affected by the water table to micro-irrigation. The rest remains under flood irrigation although they have plans to continue installing micro-irrigation.

Wal has installed three sets of tensiometers over his block and has been using them to customise the irrigation on the micro-irrigated blocks. He has found that his experience mostly matches the tensiometer readings, but he has adjusted run times according to the meter readings (eg he found in his apricot block that four to five hours was too long and so reduced it to three hours). He has been able to do this partly because he has a well he can pump out of on demand. The well is not high yielding but provides enough to irrigate the blocks under micro irrigation.

Growers in this segment around Tumut and Batlow have installed micro-irrigation to maximise fruit production from limited water supplies. These growers may experiment with monitoring but are unlikely to rely primarily on monitoring to schedule irrigations unless it is clearly demonstrated to be more accurate than conventional scheduling methods.

> *Wayne runs a large apple orchard in Batlow. Originally the property was irrigated with a mobile pipe and sprinkler system. This system used a lot of water, irrigated the entire orchard floor and was very time consuming to move around. Now Wayne has a mixture of microjet and drip irrigation. He finds that drip irrigation is better under hail netting and he won't put in any more microjets – they get tangled up and run over. His irrigation water comes from several dams fed by springs. He has never run out of water with micro-irrigation even over the last couple of dry summers.*
>
> *Wayne had two neutron probe sites put in last year and will be having them monitored this year. He has tried using tensiometers but they get broken and he is not sure that the readings are correct for the soil types at Batlow with apples. He is not sure of the value of the neutron probes – "what's this going to tell me that I don't already know". Wayne is involved in a national benchmarking project for the apple industry but doesn't believe it will be very useful. "We do benchmarking but I won't change anything. Nothing any good came out of benchmarking".*

Control oriented micro-irrigators

These growers have installed micro-irrigation to overcome problems with soil profiles or farm topography, or they have replanted their orchards using closer planting techniques. These growers may experience benefits from micro-irrigation in terms of reduced labour demand but this was not the primary reason for installing a micro system. These growers may experiment with monitoring but are unlikely to rely primarily on monitoring to schedule irrigations unless it is clearly demonstrated to be more accurate than conventional scheduling methods. Some growers in this segment may experiment with monitoring in determining when to begin irrigating at the start of the season.

> *Chris runs a large orchard growing stone and pome fruit in Toolamba. The orchard is micro-irrigated with the exception of 30 acres of flood irrigation under Williams pears. Chris is concerned about water as last year he had to buy 100 ML of water that cost a lot of money. This season*

he will be trying Partial Rootzone Drying on the Williams (basically irrigating alternative rows).

During the season blocks are irrigated every second night. Chris irrigates at night to get cheaper power and also because there is less evaporation. There are some tensiometers on the property that he uses to decide when to put the first irrigation of the season on. Chris has a ground water pump so he has no problems with salinity or a high watertable.

Chris converted to micro because when replanting they close planted stone fruit on trellises. Other issues like being able to spray and pick without interfering with irrigation were acknowledged as benefits but were not the main reasons for converting to micro-irrigation.

Kevin and Mary are in a similar position to Chris.

Kevin and Mary run a small orchard in East Shepparton. They grow pome and stone for the canning and fresh markets. They have just finished converting their property to microjets. Kevin and Mary mainly converted to micro because they have close planted fruit on trellises. However, time and labour are big issues for Kevin even though his extended family help in the shed grading and packing. He and Mary must still pick fruit, organise spraying, and transport the fruit to the cannery and market. Being able to spray and pick while irrigating is an extra benefit of converting to micro-irrigation.

Currently Kevin and Mary irrigate most blocks every eight to ten days for eight hours or more depending on the weather. As blocks get closer to harvest they increase the amount of water they apply. Kevin is concerned they may be over irrigating as they have a problem with excessive vigour in most blocks. Over the last few years he has had trouble sizing fruit and getting a good crop on some blocks. Kevin is interested to see whether soil moisture monitoring would help with these problems.

Control can also be a major issue for large orchards.

Claudio's family manages a large scale orchard and fruit packing business in Ardmona. He grows fresh market and canning pears, apples and stone fruit. The majority of the orchard is under microjets with the remainder on knocker sprinklers. They converted to micro-irrigation in 1982 because they couldn't manage their spray program and the flood irrigation. With micro-irrigation root growth is promoted in the treeline and young trees can be 'fertigated' (fertiliser put through the irrigation line). "You can irrigate trees when you want to irrigate the trees."

Changing over to micro-irrigation has resulted in water savings as well. Before they regularly used all of the water right plus half again in sales water. Now they use 80 per cent of their water right. The amount of labour for flood irrigation was an issue but being able to control the

irrigation was the main reason for converting. The ultimate goal for Claudio is to computerise the whole irrigation system using a timer program.

A consultant is employed to schedule the irrigations. Claudio gets a report every week outlining what needs to be irrigated, when and how much. The consultant is "another set of eyes for Claudio". He is occasionally surprised by the consultant's report, usually when it has been very hot and he expects the trees to want water. But underneath it may still be quite wet. If he is not happy with what the report says he will go out and check himself. They work with the four day ordering system by having a standing water order.

Claudio had salinity problems 20 years ago but has not had a problem since installing microjets.

Market segments for soil moisture monitoring

The market segments for irrigation technologies that have been described lead to four potential market segments for objective soil monitoring (see figure 2). These are:

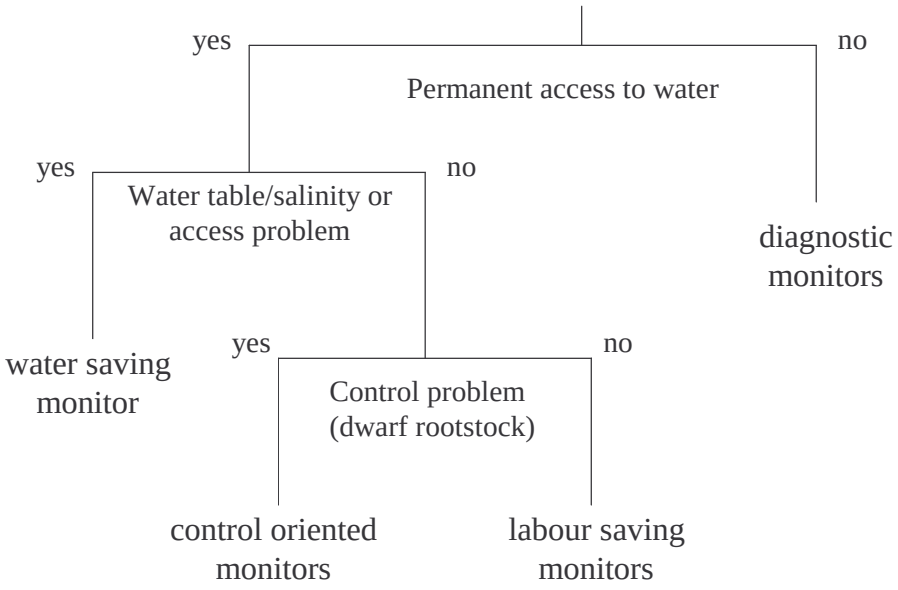
Water saving 'monitors'

One reason growers might adopt monitoring is because they continue to experience problems with rising water tables or soil salinity despite installing micro-irrigation. Growers in this situation have a pressing need to continue reducing water use. Consequently, they may consider experimenting with objective soil monitoring to schedule irrigations (and to institute RDI). We have yet to interview a grower in this situation.

A second reason growers might adopt monitoring to save water is because they installed micro-irrigation to overcome a labour constraint and over time they have expanded the area under irrigation and now face a water constraint. We have yet to interview a grower in this situation.

A third reason growers might adopt monitoring to save water is because although they have installed micro-irrigation they still face a water supply constraint. These

Market Segments for Soil Monitoring



growers may consider monitoring if they have continuous access to irrigation water. These growers may use a commercial monitoring service or install their own monitoring system.

Pete runs a small apple and cherry orchard in Batlow. The entire orchard is under microjet irrigation, supplied by a dam on the property that collects run off from the top of the catchment. Since Pete bought the orchard he has replanted the majority of trees to closer planting. With more trees on the property Pete has run into water problems. The dam does not hold enough water for the whole orchard now and must be expanded. When the dam was put in he was told he didn't need a licence. With the water reforms underway Pete is still waiting for permission to extend the storage capacity of the dam.

Pete has used the neutron probe monitoring service run by the Batlow Co-op and has eight years of data. This has enabled him to save water by customising the irrigation on each block.

Pete has stopped using the probe service because it is expensive and sometimes he has not got the water to irrigate when he needs to. He is planning to get a Gopher to monitor and schedule himself but lack of water and a couple of bad years means that this has been put off for a while. Pete has limited time so automating would be useful but he has no money to convert the system to an automatic one at present.

There are other growers around Tumut and Batlow who use monitoring to save water.

Andre has an apple orchard on the outskirts of Batlow. Andre says "limited water has forced us to use best practice." His orchard is all under drip irrigation and he uses a neutron probe service from the local co-op. The monitoring has been useful for diagnosing how effective his irrigation has been. He used to irrigate for 10 hours per week. However, after looking at the neutron probe data they moved to two five hour irrigations a week depending on the weather and are now "saving quite considerable amounts of water".

Andre "can't afford to be casual about water." He harvests water from a creek and pumps it into a storage dam. The amount of orchard planted is constrained by the amount of water that can be harvested and stored. In the future Andre is considering closer plantings with dwarf rootstocks. Water will become even more important then.

Although his irrigation system is run manually Andre has no problems with labour and so automation is not a priority. Irrigation is not often a time consumimg task given Batlow's rainfall. Andre may only have to irrigate for one week in a season.

The growers in this segment are unlikely to use objective soil monitoring to schedule irrigations unless such monitoring is clearly demonstrated to be at least as accurate as conventional scheduling methods.

Time saving 'monitors'

Another segment of growers might adopt monitoring because they installed micro-irrigation to overcome a time or labour constraint and wish to upgrade to an automated system to further reduce labour requirements. They may consider objective monitoring if they have continuous access to irrigation water.

> *Matt and Sally run a fresh stone orchard in Tresco. The whole property is under micro-irrigation. A year after converting their property to micro irrigation, Sally and Matt installed tensiometers that were hooked up to irrigation valves. The system now runs entirely automatically. Matt sets the level on the tensiometers to control when the pump turns on. He has found that there needs to be some time for drying out between irrigations otherwise the trees get too much water. In the first year after the tensiometers were installed Matt ran the system manually to monitor the tensiometers performance. Sally normally places a standing water order each month (eg 0.5 ML/day). With the system switching on and off through the tensiometers this water could be taken at anytime. They were able to automate their irrigation using tensiometers because they have irrigation water delivered via a pipeline so water is permanently available.*
>
> *Recently Matt and Sally have reclaimed salt affected land at the bottom of their property. They were able to do this because of micro-irrigation. Although tile drains were installed years ago they found that under furrow irrigation the water would push salt into the middle of the row onto the roots of the fruit trees. Under micro-irrigation the salt is pushed out and away from the roots.*

Other growers are content to automate their irrigation system using timers.

> *Roger runs a medium sized orchard in Woorinen. He converted the whole property over to micro-irrigation about 10 years ago. The property was quite difficult to irrigate using flood as it placed on the side of a sand dune. Roger has saved a lot of time and labour converting to micro irrigation. His system is hooked up to a timer system which he sets at the pump shed. Although he generally irrigates at night and on weekends on the cheaper power tariff, he will irrigate in the middle of the day if the trees need it.*

Roger has permanent access to water as he is on a main channel and has a standing order for water which he renews monthly.

Some growers are quite satisfied with the savings in time they have made by installing micro-irrigation and are not planning to go any further.

Ivan has a large orchard near Gundagai. He produces stone and pome fruit using mini-sprinklers (micojets). He has both a high security and low security irrigation licence. Ivan pumps his water directly from the Murrumbidgee river.

Originally Ivan grew vegetables using drip irrigation but experienced problems with frequent line blockages. He then moved to flood irrigation using movable pipes. Over the years the demands this method of irrigation placed on labour became unsustainable. Ivan converted to mini-sprinklers about twenty years ago. Ivan believes mini-sprinklers work better than drip systems because they are not as sensitive to blockage from silt and are easier to clean out. Ivan also installed a settling pond to reduce the silt content of his irrigation water.

Ivan does not plan to install monitoring. He will attend a workshop on monitoring but feels that 'even though he might learn something' he 'probably wont change his practice'. Ivan believes that subjective assessment of soil moisture is accurate enough for his situation. In Ivan's words 'I have been doing it [irrigating] for fifteen years without any problems. If I had any problems I'd have done something about them'.

Control 'monitors'

A third segment includes growers who might adopt monitoring is because they installed micro-irrigation to manage a control problem and wish to refine their control over irrigation. For example, monitoring may be used to assist in controlling vigour through RDI. It may also be used to assist in irrigating dwarf rootstock.

Clive and Carmel run a large orchard near Batlow. They grow a mix of apples and stone fruit. Their orchards are under drip irrigation for supplementary watering during the growing season. Their water supply comes from several dams fed by springs. They do not have a problem getting enough water.

Carmel and Clive have used the local neutron probe service in the past but have just purchased a Gopher. They are moving towards dwarf

rootstocks to control vegetative growth on their apples, thereby reducing the amount of ladder work and pruning. Dwarf rootstocks have a very shallow root system so timing and application of irrigation water to the tree becomes important. "If you're going to go for dwarf rootstocks you have to go this way [putting in soil moisture monitoring]." Carmel and Clive believe "there is scope to be more efficient but not that much" as they have already customised their irrigation over the years.

The growers in this segment are unlikely to use objective soil monitoring to schedule irrigations unless such monitoring is clearly demonstrated to be at least as accurate as conventional scheduling methods. These growers must have continuous access to irrigation water.

Diagnostic 'monitors'

A fourth segment includes growers who might adopt monitoring (such as tensiometers) to assist them in a variety of ways. These growers may be on flood or micro-irrigation. These growers to not have continuous access to irrigation water and must order water in advance. Consequently, it is not practical for these growers to use soil moisture monitoring to schedule their irrigations.

These growers might use monitoring to help them determine when to commence the irrigation season. They may also use monitoring to evaluate and improve their irrigation performance over the season, especially in terms of irrigation run-times and frequency. For instance, by altering irrigation run-times, growers may reduce water use so their blocks dry out faster. Examples of growers in this segment can be found in the descriptions of the market segments for irrigation systems.

Conclusion

During interviews with fruit growers we found that the installation of micro-irrigation was a major factor affecting the use of objective monitoring of soil moisture for irrigation scheduling. Consequently, we concentrated first on describing the factors influencing the adoption of micro-irrigation. We found growers adopt micro-irrigation to either save water to manage a salinity or water table problem, to save labour and time, or to increase control over the timing or application of watering. We found some growers around Batlow and Tumut have adopted micro-irrigation to save water because of limited water supplies.

We found that growers who have installed micro-irrigation are unlikely to adopt monitoring unless it is demonstrated to be easy to use and more accurate than experience.

Most growers are in a position to use soil moisture monitoring (such as tensiometers) to assist them in deciding when to commence the irrigation season. Most growers may also be able to use monitoring to assist them to optimise their irrigation management in terms of irrigation frequency and run-times. However, as a general rule, growers are too constrained by access to water, the cost of power and the scheduling of other farm activities to use monitoring to directly schedule irrigations during the season. Only growers who have access to permanently available water (growers at Swan Hill or growers with on-farm storage at Tumut or Batlow for example) are in a position to use monitoring to schedule irrigations throughout the season.

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Soil Monitoring, Irrigation Scheduling and Fruit Production

PART TWO

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Soil Monitoring, Irrigation Scheduling and Fruit Production

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Executive Summary

In this study we investigated the major forces driving the adoption of micro-irrigation and soil moisture monitoring by stone and pome fruit growers. A mail survey was sent to 780 fruit growers from the Shepparton, Cobram, Swan Hill, Tumut and Batlow districts.

The results from the survey of fruit growers indicate the major forces driving the adoption of micro-irrigation are:

- The shift to trellis and closer planting techniques;
- A need to reduce time spent irrigating; and
- A need to increase flexibility in managing irrigation, spraying and picking activities in the orchard.

These findings lead to the conclusion that the area under flood irrigation will continue to decline as growers redevelop orchards and as the demands on grower's time increase, especially in periods when activities such as irrigation, spraying and picking coincide. These findings also suggest the rate of adoption of micro-irrigation may be influenced indirectly through activities that promote trellising and closer planting techniques to growers who are redeveloping their orchards.

Increasing water use efficiency was not identified by most fruit growers as a factor in the adoption of micro-irrigation. This suggests it is unlikely that extension activities aimed at promoting an increase in water use efficiency will have a substantial influence on the rate of adoption of micro-irrigation.

The results from the survey of fruit growers indicate the adoption of soil moisture monitoring is strongly associated with:

- Problems of high water tables, salinity or tree vigour;
- A need on larger orchards to check irrigation performance; and
- Planting of dwarf rootstocks.

The keys to successfully adopting soil moisture monitoring are the use of micro-irrigation and immediate access to irrigation water (water on demand). Growers with flood irrigation appear to derive little benefit from monitoring because they do not have the flexibility necessary to adjust their irrigation scheduling. Growers with micro-irrigation who cannot water on demand also experience difficulties with using monitoring to schedule because they are unable to adjust ordering of irrigation water appropriately.

Growers with micro-irrigation who do not have access to water on demand adopt monitoring either to resolve problems with tree health or tree vigour, or to help determine the timing of the first irrigation of the season.

It appears that among growers who have access to water on demand and who use micro-irrigation, those with larger orchards may adopt monitoring to check on irrigation performance. This suggests there may be an opportunity to actively promote monitoring as a scheduling tool to growers with larger orchards.

Increasing water use efficiency was not identified by fruit growers as a factor in the adoption of soil moisture monitoring. This suggests it is unlikely that extension activities

aimed at promoting an increase in water use efficiency will have a substantial influence on the rate of adoption of soil moisture monitoring.

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We are indebted to the fruit growers 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

In this report we describe the results from the second stage of a study into the adoption of irrigation systems and soil moisture monitoring by stone and pome fruit farmers.

In the first stage of the study we interviewed thirty fruit growers (as well as research and extension staff) to identify the factors that influence the adoption of irrigation systems and soil moisture monitoring (Kaine and Bewsell 1999). In the second stage of the study we conducted a mail survey of fruit growers in the Shepparton, Cobram, Swan Hill, Tumut and Batlow districts. The purpose of the survey was to quantify the relative importance of the factors influencing the adoption of irrigation systems and soil moisture monitoring. 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 fruit growers who responded to the survey are outlined. The market segments for micro-irrigation resulting from a statistical segmentation analysis of the data are described in the next section. This is followed by a description of the market segments for soil moisture monitoring. In the final section of the report some preliminary extension strategies are proposed.

The questionnaire

The interviews conducted in the first stage of the study revealed that the adoption of micro-irrigation depended on a number of key factors. These factors were:

- A need to reduce the use of irrigation water to overcome problems with tree health caused by salinity or a high water table.

- A need to reduce the use of irrigation water to maximise production from limited water supplies.

- A need to reduce the amount of time spent irrigating and to increase managerial flexibility in the orchard.

- The redevelopment of orchards through closer planting techniques.

- Micro-irrigation is often the only form of irrigation suitable for those on hilly or sandy country.

The interviews also revealed that the key factors influencing the adoption of soil moisture monitoring are.

- Access to continuously available irrigation water.

- Installation of a micro-irrigation system.

- A need to reduce the use of irrigation water to overcome problems with tree health caused by salinity or a high water table.

- A need to reduce the use of irrigation water to maximise production from limited water supplies.

- A need to reduce the amount of time spent irrigating.

- The redevelopment of orchards through closer planting techniques and dwarf rootstocks.

These key factors lead us to design a questionnaire in three parts. The first part sought information on some basic orchard characteristics such as orchard size, tree types, the length of irrigation season and so on (see appendix A). The second part

was designed to elicit information on the irrigation systems used in the orchard such as type of irrigation system, area of orchard irrigated using each system, method of ordering irrigation water, and so on. Information was also sought in this section on grower's reasons for installing micro-irrigation systems. Respondents were asked to indicate which of the key factors that influence the adoption of micro-irrigation best described their reasons for installing micro-irrigation. In the third part of the survey information was sought on the use of soil moisture monitoring systems. Respondents were asked to indicate which of the key factors that influence the adoption of monitoring best described their reasons for trying or using soil moisture monitoring.

The questionnaire was printed in the form of a 12 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 fruit growers in the Shepparton, Cobram and Swan Hill districts of Victoria and the Tumut and Batlow district of New South Wales. The population of growers in these districts is approximately 780 (650 in Victoria and 130 in New South Wales).

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. Forty-four questionnaires were returned with incorrect addresses or from people who were not fruitgrowers. This gave an effective mail out of 736 questionnaires. A total of 251 questionnaires had been returned some ten weeks after the initial mailing. This represents a response rate of 34 per cent.

Approximately 41 per cent of returns came from Shepparton and surrounding districts, 17 per cent from Cobram and surrounding districts, 22 per cent from Swan Hill and surrounding districts. This represents 33 per cent of stone and pome fruit growers and approximately 49 per cent of the area planted to stone and pome fruit in the northern irrigation region of Victoria.[1] Some 14 per cent of responses were from

[1] These results are calculated from the 1997 Irrigated Farm Census (Douglass, Poulton et al. 1998).

growers in Tumut and Batlow. Five per cent of surveys were returned by growers from areas outside the target districts.

The general characteristics of the sample are reported in table 1. In the table the average area of orchards in each district and the proportion of orchards in each district planted to different types of fruit trees are reported. Also reported in the table is the average proportion of orchard area under the different types of irrigation systems in each district.

The average area of orchards was not significantly different across the districts.[2] The proportion of orchards in each district planted to different types of fruit trees was significantly different across districts reflecting different growing environments.[3]

The proportion, on average, of orchard area under the different types of irrigation systems was significantly different across districts.[4] When fruit growing commenced in the older districts of Shepparton and Swan Hill the only irrigation techniques available were bay or furrow flood irrigation. Under-tree knocker sprinklers had been developed when fruit growing began in Cobram. Consequently, flood irrigation in Shepparton and Swan Hill is based on bay or furrow irrigation whereas under-tree knocker sprinklers are the predominate form of flood irrigation in Cobram.[5] The topography in Tumut and Batlow does not suit flood irrigation hence micro-irrigation is the only form of irrigation in these districts.

Growers have converted to different forms of micro-irrigation depending on the location. For example, in Swan Hill growers have mostly converted from furrow flood irrigation to drip irrigation. In Cobram, growers have mostly converted from under-tree knocker sprinklers to mini-sprinklers. In contrast many Shepparton growers have converted from flood irrigation using bays to micro-jets. Discussions

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[2] For orchard area $F_{3,219}=2.3$, p=0.08.
[3] For apples $\chi^2=137.8$, p=0.00, for pears $\chi^2=155.8$, p=0.00, for cherries $\chi^2=19.1$, p=0.00, for peaches $\chi^2=27.3$, p=0.00, for nectarines $\chi^2=61.7$, p=0.00, for apricots $\chi^2=38.8$, p=0.00, for plums $\chi^2=29.4$, p=0.00.
[4] For proportion of orchard irrigated by flood $F_{4,227}=8.2$, p=0.00, by under-tree knocker sprinkler $F_{4,227}=29.6$, p=0.00, by micro-jets $F_{4,227}=11.5$, p=0.00, by mini-sprinklers $F_{4,227}=8.7$, p=0.00, by drip $F_{4,227}=58.0$, p=0.00.

with research and extension staff of the Department, and irrigation consultants indicated that there are a number of reasons for these district differences.

[5] This information is based on conversations with the district horticultural extension officer and irrigation consultants.

Table 1: Orchard characteristics by district

	Shepparton[1]	Cobram[2]	Swan Hill[3]	Tumut/Batlow
Average orchard area (ha)	32.5 (1.2 - 260.0)	34.3 (2.0 - 405.0)	14.2 (0.8 - 120.0)	56.3 (3.2 - 800.00)
Average percentage of orchard area under:				
Flood irrigation*	27.4	8.7	34.3	-
Under-tree sprinkler irrigation*	6.7	39.6	1.2	-
Micro-jet irrigation*	37.1	14.8	3.0	25.6
Mini-sprinkler irrigation*	18.5	33.1	1.8	6.7
Drip irrigation*	6.1	-	55.3	67.5
Percentage of orchards growing:				
Apples*	92	40	2	91
Pears*	93	60	-	3
Cherries*	6	10	-	26
Peaches*	50	93	71	46
Nectarines*	21	60	86	60
Apricots*	51	45	69	3
Plums*	55	53	78	20
Irrigation season (months)*	5.5	5.8	7.1	5.3

Notes: An asterisk denotes a statistically significant difference between the districts.
The numbers in parentheses are ranges.

1. Includes East Shepparton, Ardmona, Tatura and Kyabram.
2. Includes Invergordon.
3. Includes Tresco, Woorinen and Nyah.

- First, when converting older plantings to micro-irrigation, tree spacing may have an influence on the type of micro-irrigation that is considered most suitable. For example an older, flood irrigated pear block may be planted on a 20 by 20-metre spacing. The root systems of trees in such blocks will tend to spread away from the treeline into the irrigation bays. Consequently, this type of block would generally be converted to mini-sprinklers or large area micro-jets so that the root area can be irrigated. This type of tree spacing is typical in Shepparton and Cobram.
- Second, the conversion to micro-irrigation may be influenced by the irrigation infrastructure already in place. For example, in Cobram the conversion to mini-sprinklers is relatively easy as the pump and piping required for this type of system is already in place for irrigating with under-tree knocker sprinklers.
- Third, the climate and soils in a region may influence the conversion to micro-irrigation. The drier climate and lighter soils in Swan Hill favour conversion to drip irrigation. Also, as bay irrigation was impractical on the lighter soils in Swan Hill furrow irrigation along treelines was the main form of flood irrigation used in the area. This favoured the conversion to drip irrigation, as the root systems of fruit trees tend to follow the treeline.
- Fourth, the irrigation designers and suppliers of irrigation equipment may also have some influence over the type of micro-irrigation adopted through their experiences with the performance of different types of micro-irrigation systems in different areas.
- Finally, the way in which irrigation water may be ordered could influence the type of micro-irrigation installed. Mini-sprinklers and micro-jets require relatively greater volumes of water at higher pressures for shorter periods than drip or trickle irrigation systems. Hence, mini-sprinkler and micro-jet systems are more practical in situations where irrigation water is not available on demand and must be ordered in advance.

The period over which growers in each district are irrigating is also reported in table 1. The irrigation season in Tumut and Batlow is shorter, on average, than in other

districts. In contrast, the irrigation season in Swan Hill is longer, on average, than in other districts.[6] These results match the experience of extension staff.

Irrigation system segments

Interviews with fruit growers in the qualitative stage of this study revealed that fruit growers adopt micro-irrigation:

- To increase production by irrigating a greater number of trees when the supply of irrigation water is limited.
- To reduce water use when they need to manage a watertable or salinity problem, or when they are experiencing difficulties with the irrigation delivery system.
- To reduce the demands irrigation imposes on labour and to overcome the constraints flood irrigation imposes on the conduct of other orchard activities such as spraying and picking.
- To irrigate orchards that have been developed using closer planting or trellis planting techniques.

In the survey fruit growers were asked to indicate the type of irrigation system they used in their orchards. If growers used a micro-irrigation system they were also asked to select from a list of statements those statements which best described their reasons for adopting micro-irrigation (see figure 1). Five variables were constructed from the responses to these questions to classify fruit growers into irrigation system segments.

For the purpose of the segmentation analysis, irrigating with under-tree knocker sprinklers was categorised as a type of flood irrigation, along with bay or furrow irrigation. We treated irrigating with under-tree knocker sprinklers as a form of flood irrigation systems because, like bay and furrow irrigation, it imposes constraints on the conduct of other orchard activities such as spraying and picking because they involve wetting the entire orchard floor. This is not the case with any of the micro-irrigation systems.

[6] For length of irrigation season $F_{3,215}=7.4$, $p=0.00$.

Q2-1 What percentage of your orchard do you irrigate with the system listed below?

Type of irrigation:	*Percentage of orchard*
Flood (bay or furrow)	
Under-tree knocker sprinklers	
Micro-jets	
Mini-sprinklers	
Drip or trickle	

Q 2-7. Have you installed micro-irrigation (ie trickle, drip, micro-jet or mini-sprinkler)? ❑ **YES** ❑ **NO**

If **YES**, which of the following reasons best describes why?

- I have been redeveloping blocks to closer plantings or plantings on trellis.
- I have converted to micro-irrigation to save on time and labour spent irrigating.
- I have been installing micro-irrigation because it increases my flexibility in terms of picking and spraying.
- I installed micro-irrigation because of tree health problems due to groundwater, high water tables, or salinity.
- I have installed micro-irrigation because of problems getting water delivered (eg because my orchard is on a spur channel).
- I installed micro-irrigation because it best suits the soil types/ topography of my orchard.
- I installed micro-irrigation because I have limited water supplies.
- Other _____.

Figure 1: Segmentation questions for irrigation systems

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.[7] The 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 five segments were present in the sample (Aldenderfer and Blashfield 1984).

The formation of the five segments is illustrated in figure 2 and the profiles of the growers in each segment, in terms of their reasons for adopting micro-irrigation are presented in figures 3 to 6. The first of these segments, which is shown in the lower left corner of figure 2, is the 'control and time redevelopers' segment. This segment is composed of growers whose main reasons for installing micro-irrigation were to save time and labour irrigating, to increase their flexibility in terms of picking and spraying fruit while irrigating, and who were redeveloping their orchards to closer plantings or plantings on trellis (see figure 3). The growers in this segment represented approximately 23 per cent of respondents.

The second segment consisted of growers whose main reasons for installing micro-irrigation were to save time and labour irrigating and to increase their flexibility in terms of picking and spraying fruit while irrigating (see figure 4). The growers in this 'time saving converter' segment represented approximately 24 per cent of respondents.

The growers in the third segment, the 'water saving' segment, is shown in the middle of figure 2. These were growers who had installed micro-irrigation in order to manage limited water supplies, problems with salinity, water tables or water deliveries, or because micro-irrigation best suited their soils or topography (see figure 5). Approximately half of the growers in this segment were from Batlow and Tumut. This segment represented 17 per cent of the sample.

The fourth segment consisted of fruit growers whose main reason for installing micro-irrigation was because they were redeveloping their orchards to closer plantings or

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

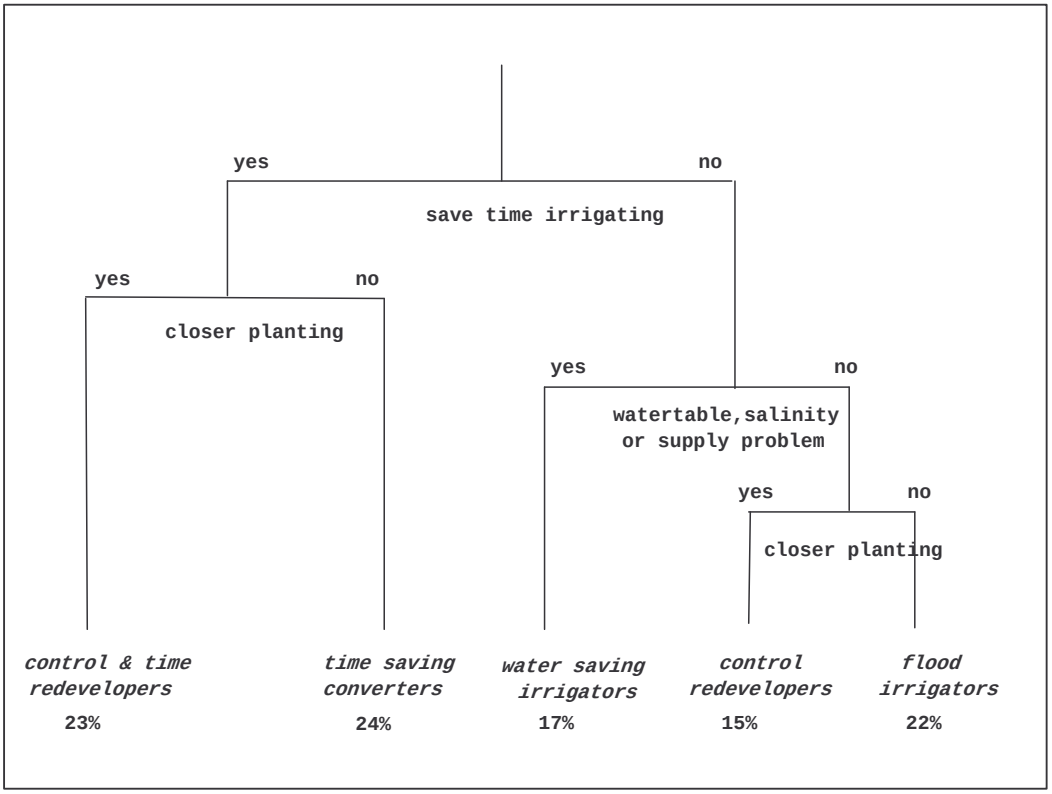

Figure 2: Formation of irrigation segments

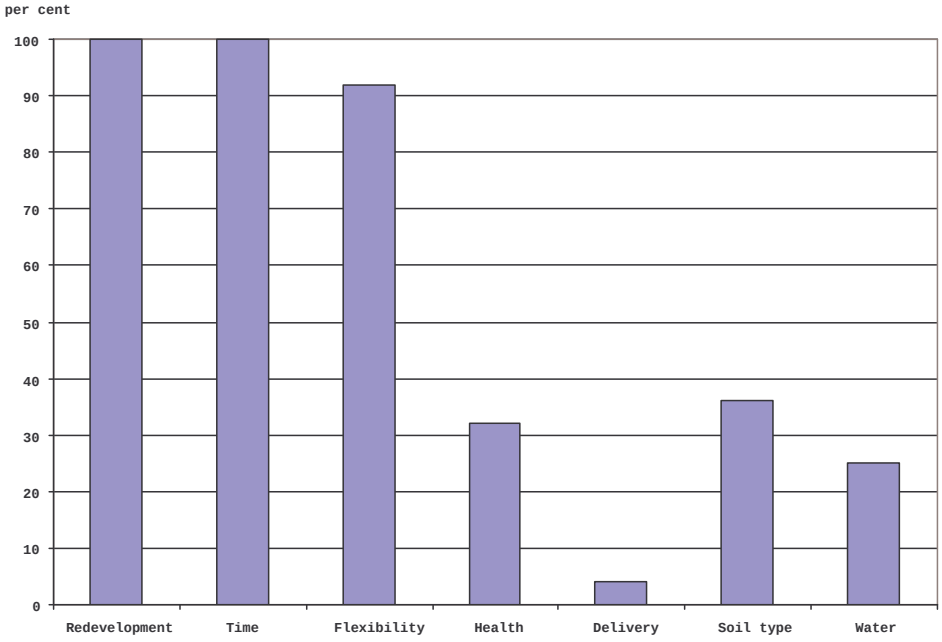

Figure 3: Attributes of the 'control and time redevelopers' irrigation segment

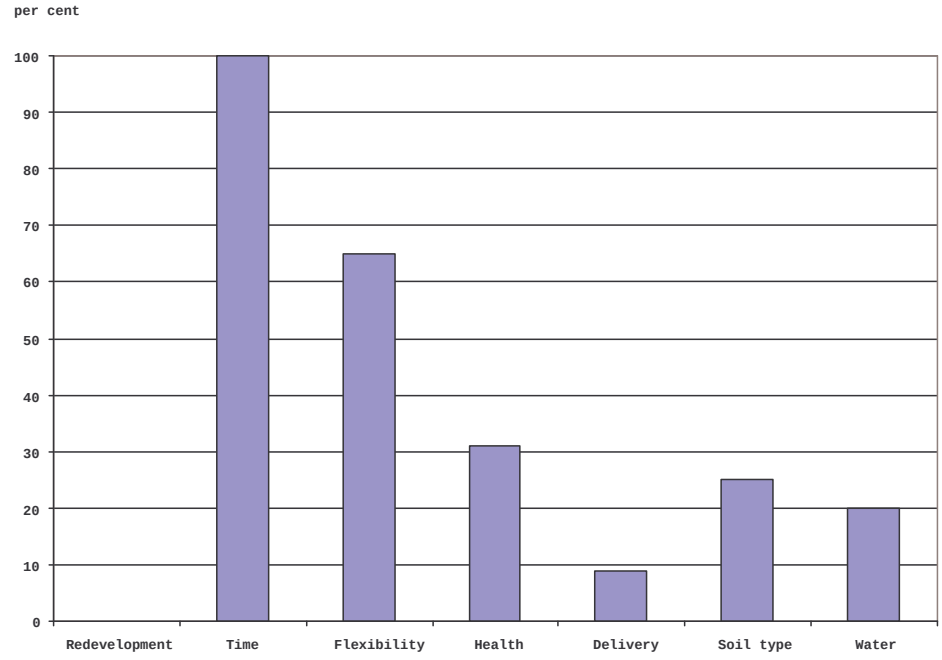

Figure 4: Attributes of the 'time saving converters' irrigation segment

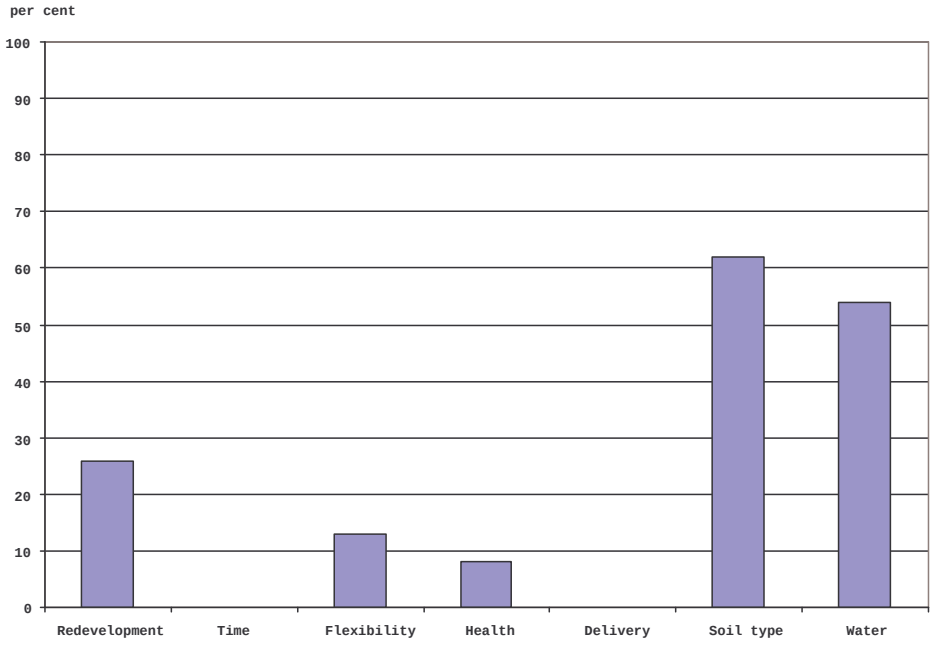

Figure 5: Attributes of the 'water saving' irrigation segment

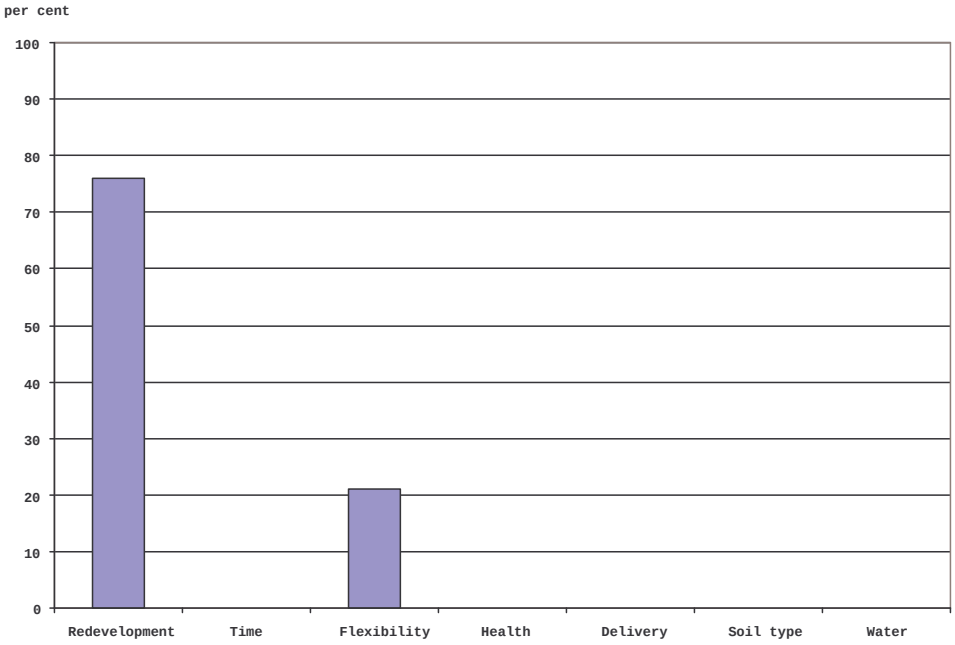

Figure 6: Attributes of the 'control redevelopment' irrigation segment

plantings on trellis (see figure 6). The growers in this 'control redevelopers' segment represented approximately 15 per cent of respondents.

The growers in the fifth segment were growers who only had flood irrigation (bay, furrow or under-tree knocker sprinklers). These growers represented 22 per cent of the sample and appear in the lower right corner of figure 2.

Characteristics of irrigation system segments

The proportion of growers from the different irrigation segments in each district is illustrated in figures 7 to 10.[8]

In Shepparton the majority of fruit growers who installed micro-irrigation belong to the 'control and time redeveloper' and the 'time saving converter' segments. This suggests that the main motivations for installing micro-irrigation in the Shepparton district are to save time irrigating, to increase flexibility in managing orchard activities and redevelopment of the orchard.

In Cobram a relatively high proportion of growers use under-tree knocker sprinklers to flood irrigate. Those fruit growers who have installed micro-irrigation belong to the 'control redeveloper' segment. This suggests the installation of micro-irrigation in the Cobram district is mainly the result of redeveloping orchards to closer plantings or plantings on trellis.

A relatively high proportion of growers in Swan Hill use furrow flood irrigation. Those fruit growers in Swan Hill who have installed micro-irrigation belong to the 'control and time redeveloper' and the 'time saving converter' segments. This suggests that growers in Swan Hill, like those in Shepparton, have converted to micro-irrigation to save time and labour, to increase flexibility in managing orchard activities and when redeveloping orchards.

[8] The differences in the distribution of irrigation segments across districts are statistically significant $\chi^2=82.2$, $p=0.00$

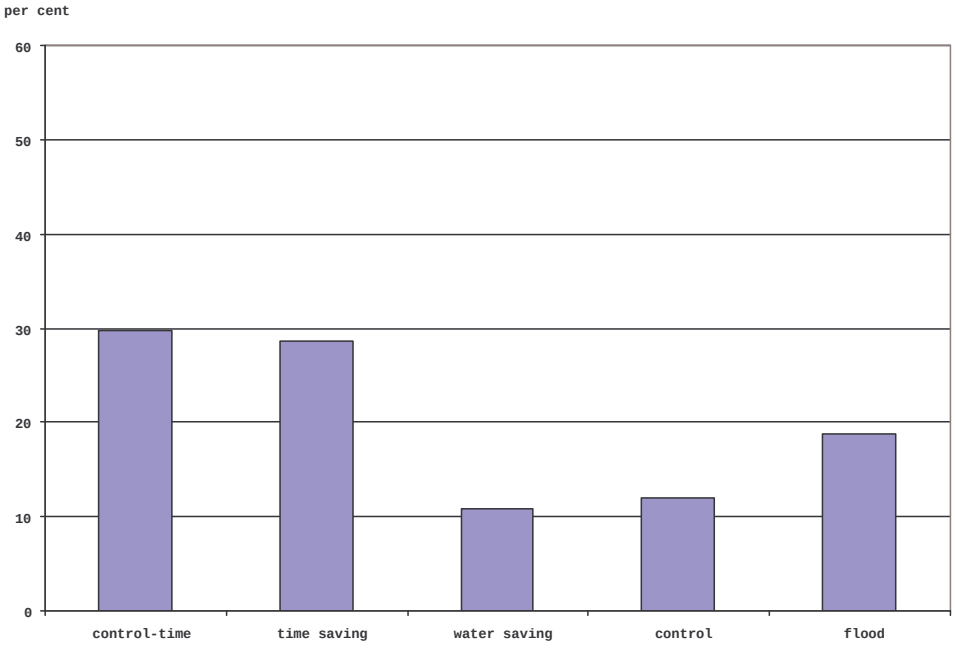

Figure 7: Distribution of irrigation segments in the Shepparton district

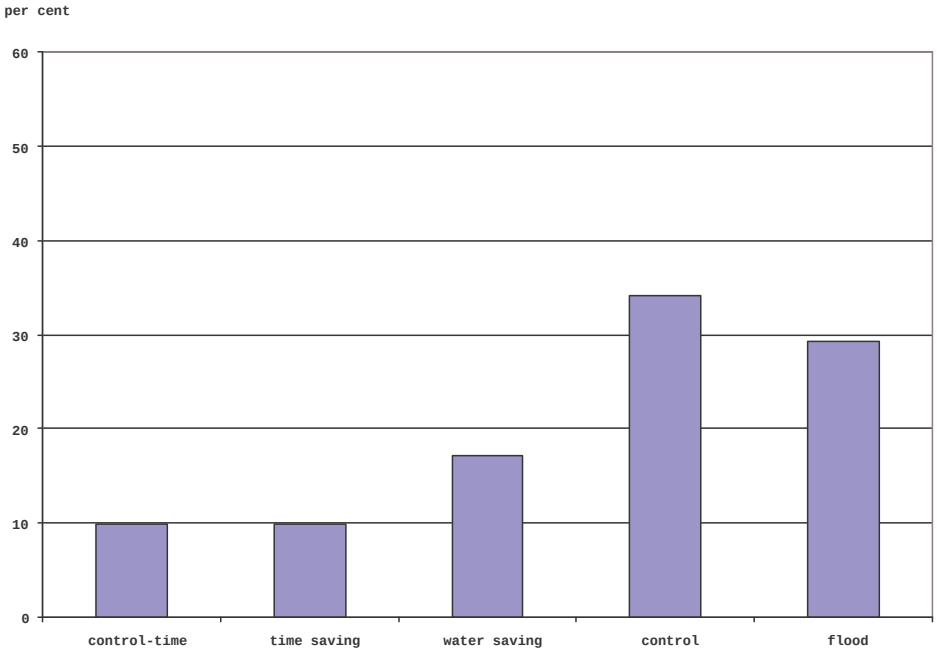

Figure 8: Distribution of irrigation segments in the Cobram district

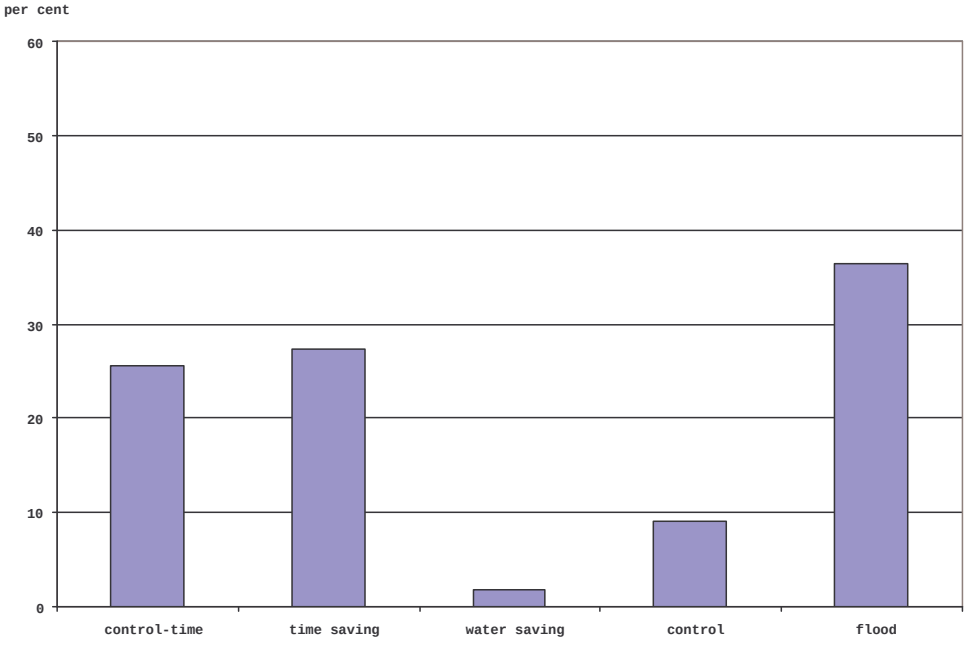

Figure 9: Distribution of irrigation segments in the Swan Hill district

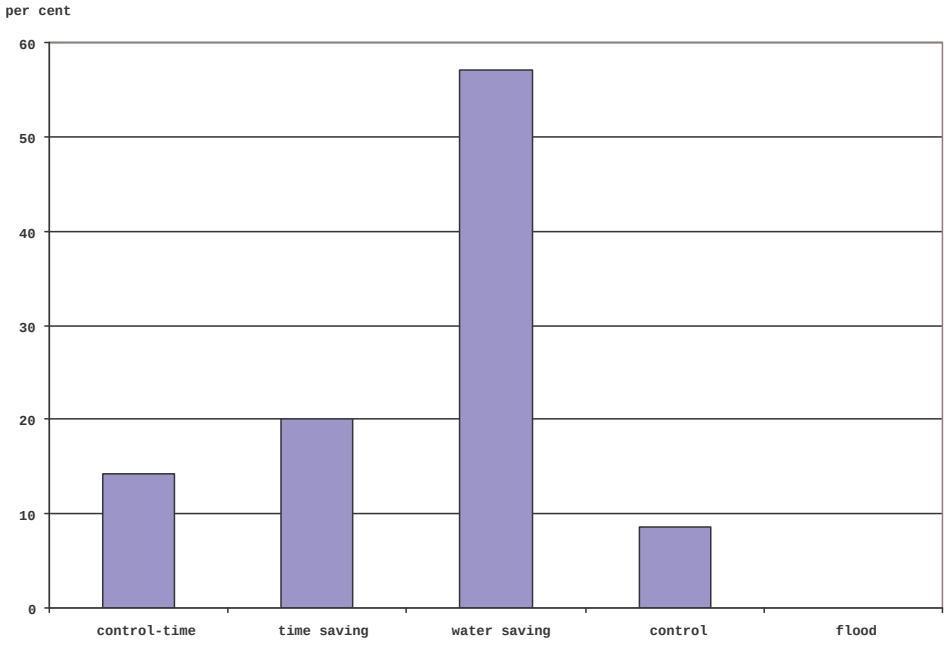

Figure 10: Distribution of irrigation segments in Tumut and Batlow

In Tumut and Batlow most fruit growers have installed micro-irrigation to save water. Consequently, growers in this district belong to the 'water saving' segment (see figure 10).

The average proportion of orchard area under each type of irrigation system is illustrated for each segment in figures 11 to 15.[9]

Fruit growers in the 'control and time redeveloper' and the 'time saving converter' segments have installed micro-jets and drip irrigation (see figures 11 and 12). The majority of the growers in these segments are from the Shepparton district where micro-jets are the predominant form of micro-irrigation, or from Swan Hill where drip is the predominant form of micro-irrigation.

Fruit growers in the 'water saving' segment have installed drip irrigation and mini-sprinklers (see figure 13). The majority of the growers in this segment are from Tumut and Batlow where drip is the predominant form of micro-irrigation. Approximately one third of the growers in this segment are from the Shepparton district. Many of these growers appear to have installed micro-jets or mini-sprinklers to overcome salinity, watertable and tree health problems.

Fruit growers in the 'control redeveloper' segment also have installed drip irrigation and mini-sprinklers (see figure 14). Approximately half of the growers in this segment are from Cobram where mini-sprinklers are the predominant form of micro-irrigation. Most of the other growers in this segment are from the Shepparton district. These growers have also installed mini-sprinklers when redeveloping their orchards to closer plantings or plantings on trellis. Growers in this segment from Swan Hill, Batlow and Tumut have installed drip systems.

Approximately one third of the fruit growers in the 'flood' segment are from Cobram and use under-tree knocker sprinklers. The other growers in this segment are from the

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[9] The differences in the proportion of irrigation systems in each segment are statistically significant. For proportion of orchard irrigated by flood $F_{4,227}=68.5$, $p=0.00$, by under-tree knocker sprinkler $F_{4,227}=6.4$, $p=0.00$, by micro-jets $F_{4,227}=12.3$, $p=0.00$, by mini-sprinklers $F_{4,227}=6.5$, $p=0.00$, by drip $F_{4,227}=8.2$, $p=0.00$.

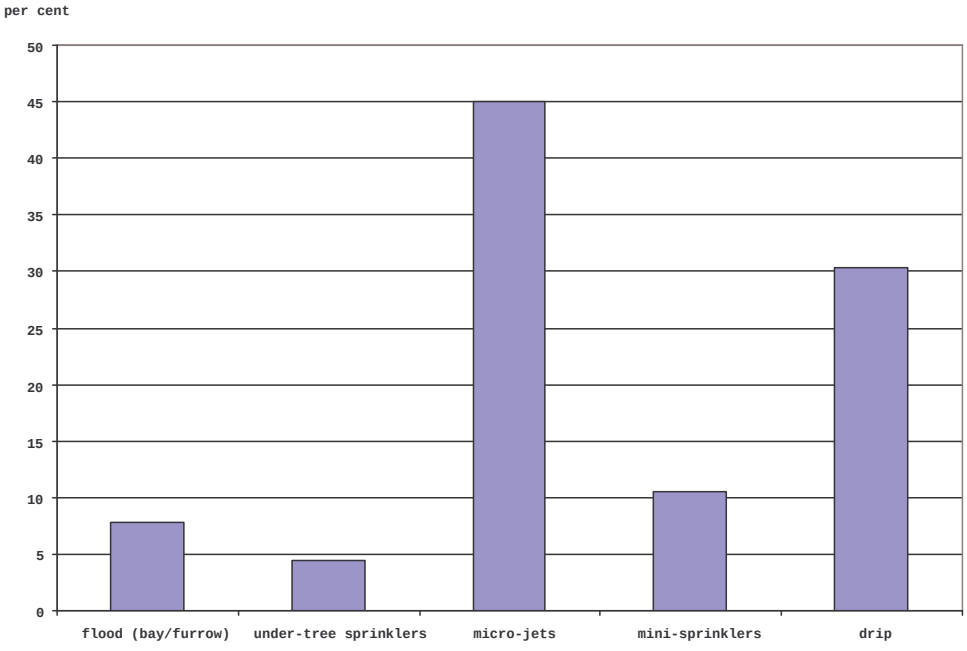

Figure 11: Irrigation systems in the 'control and time redeveloper' segment

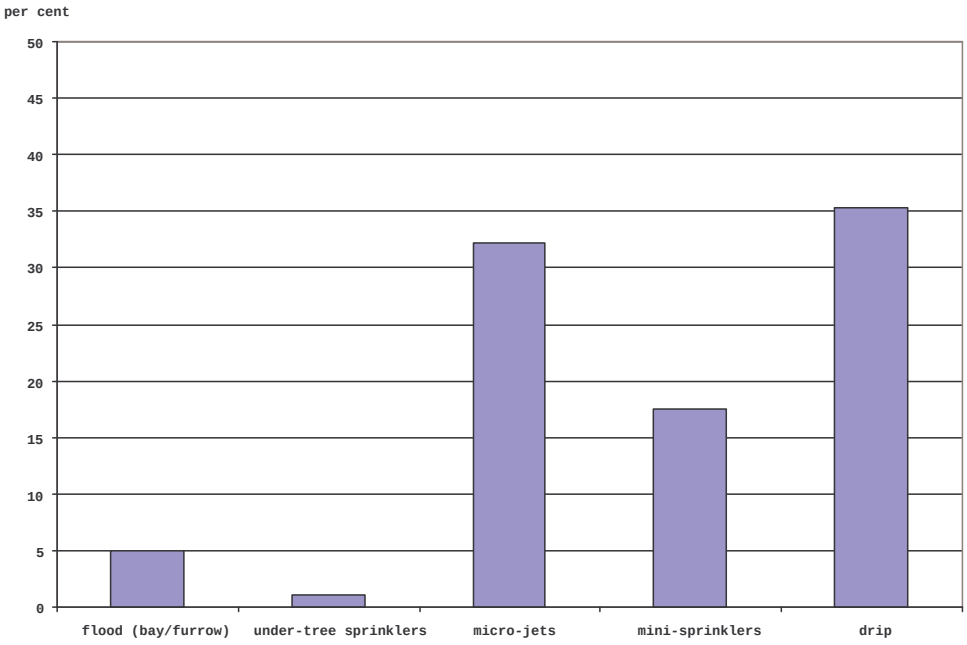

Figure 12: Irrigation systems in the 'time saving converter' segment

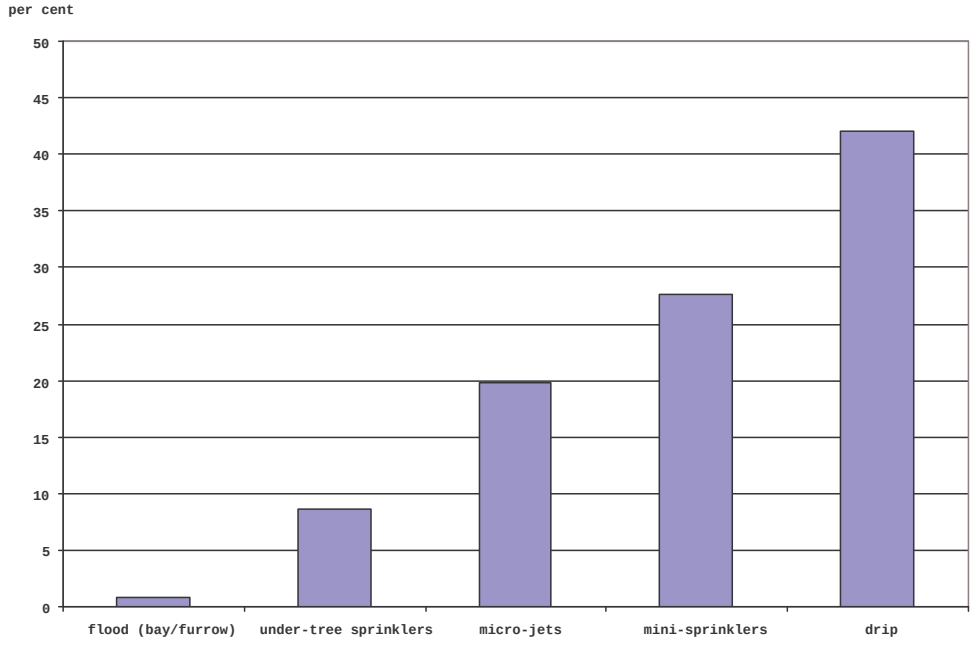

Figure 13: Irrigation systems in the 'water saving' segment

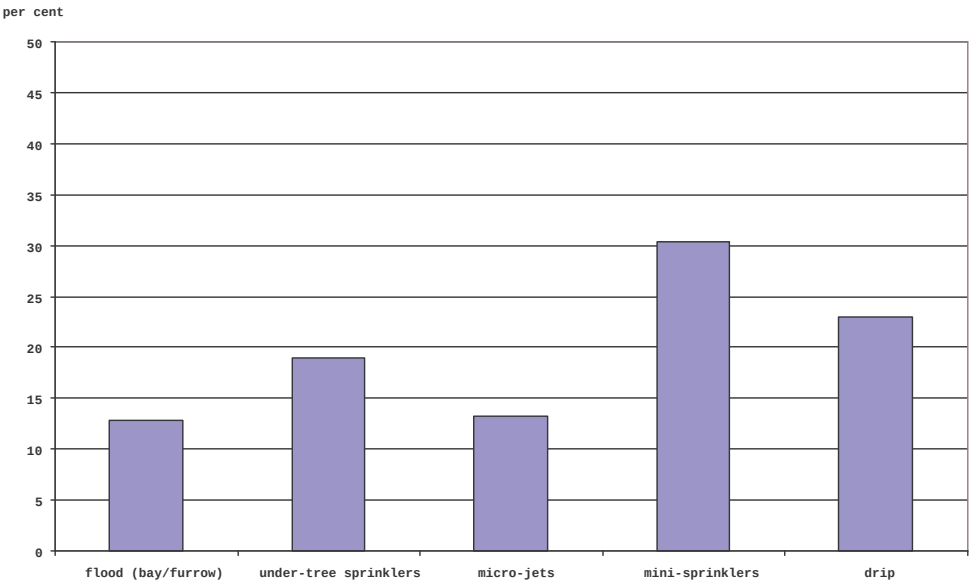

Figure 14: Irrigation systems in the 'control redeveloper' segment

Shepparton and Swan Hill districts and rely on bay or furrow flood irrigation (see figure 15).

In figure 16 the proportion of growers in each segment who have automated their irrigation systems by installing programmable timers is shown.[10] The installation of programmable systems appears to be related mostly to the need to save time irrigating and to increasing flexibility in managing farm activities in the orchard. High proportions of growers from both the 'control and time redeveloper' and the 'time saving converter' segments have installed programmable systems. However, programmable timers may be offered to growers as part of an orchard redevelopment package as they are easy and inexpensive to install during redevelopment. This may explain why a high proportion of growers in the 'control redeveloper' segment also have programmable irrigation systems.

In figure 17 the proportion of growers in each segment who have had a tree health problem caused by high water tables or salinity is shown.[11] Growers in the 'time saving redeveloper' and 'time saving converter' segments are most likely to have experienced tree health problems. A relatively high proportion of growers in the 'flood irrigation' segment indicated they have had problems in the past with waterlogging or salinity. However, many of these growers are now protected by a groundwater pump or tile drainage system.

In figure 18 the proportion of growers in each segment who have employed a consultant to help them with their irrigation management is shown.[12] A significantly higher proportion of growers in the 'water saving' segment are likely to have used an irrigation consultant or irrigation service. This result seems plausible given the priority these growers must place on irrigation to manage limited water supplies.

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[10] χ^2=11.8, p=0.02
[11] χ^2=13.9, p=0.01
[12] χ^2=16.9, p=0.01

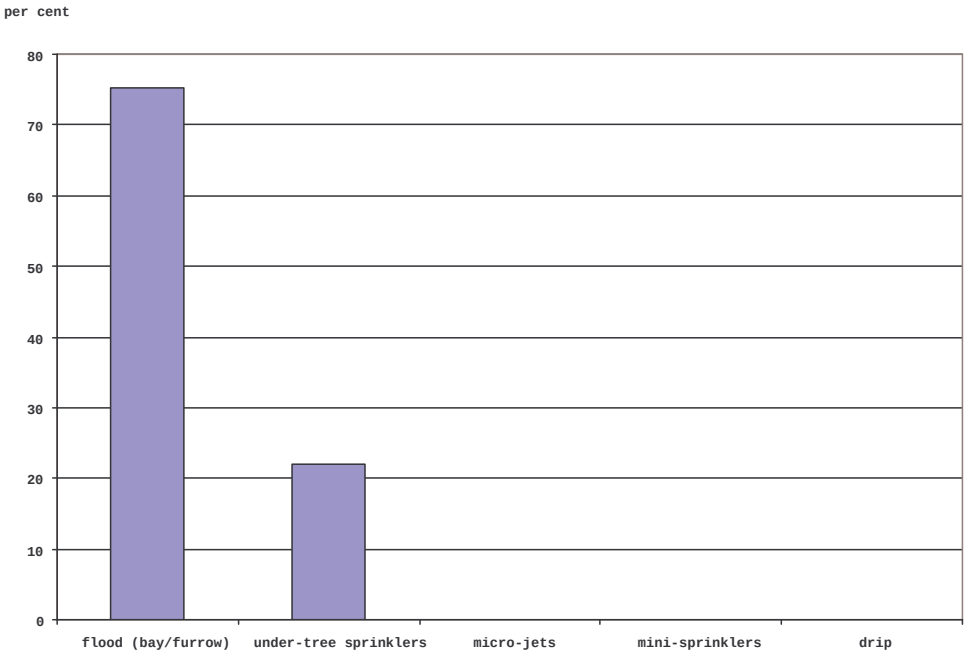

Figure 15: Irrigation systems in the 'flood irrigation' segment

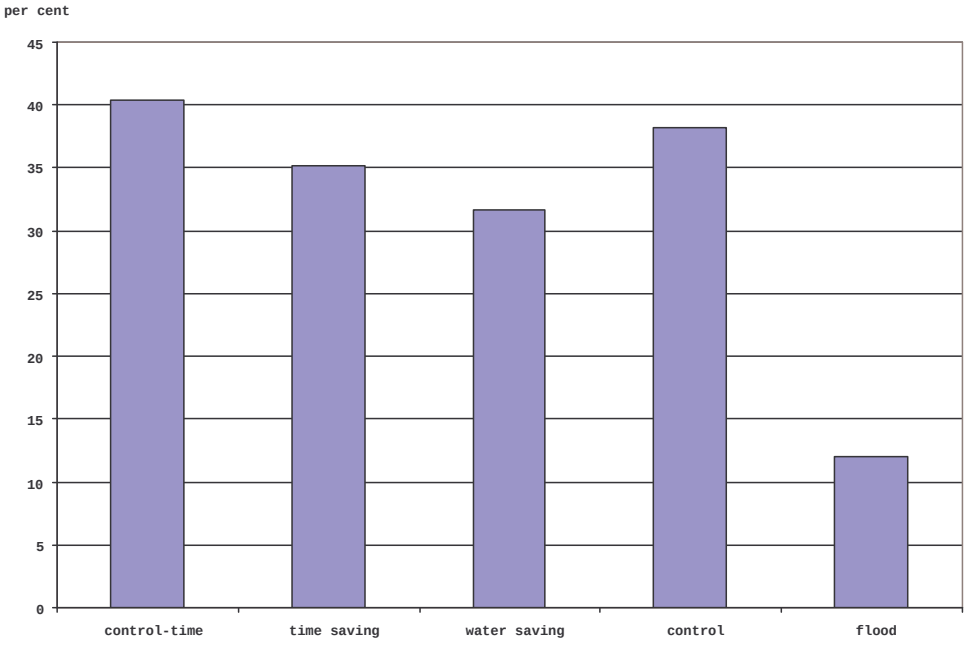

Figure 16: Irrigation systems segments and programmable irrigation systems

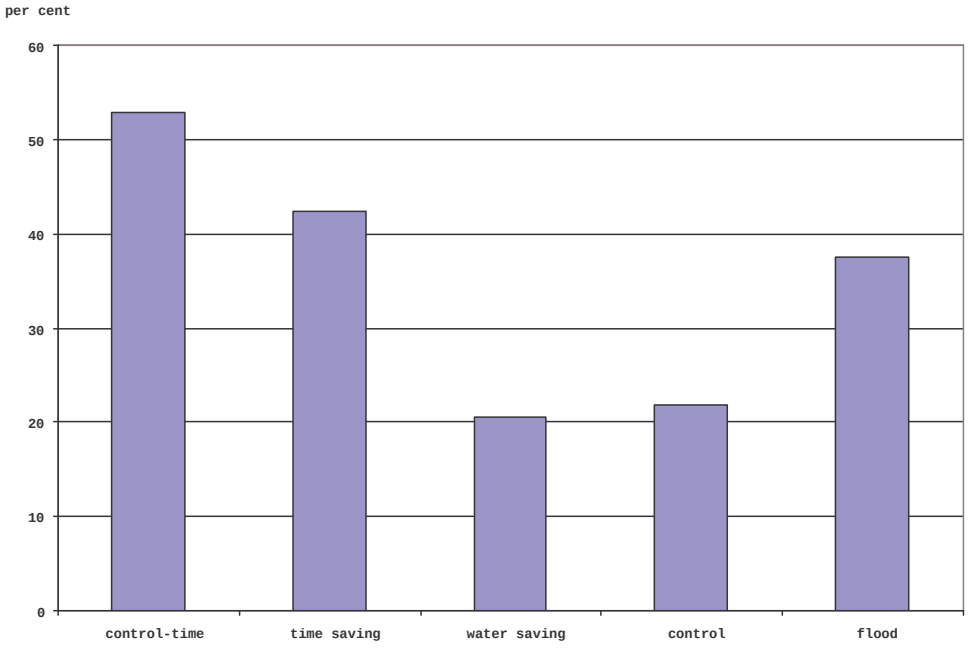

Figure 17: Irrigation systems segments and problems with tree health

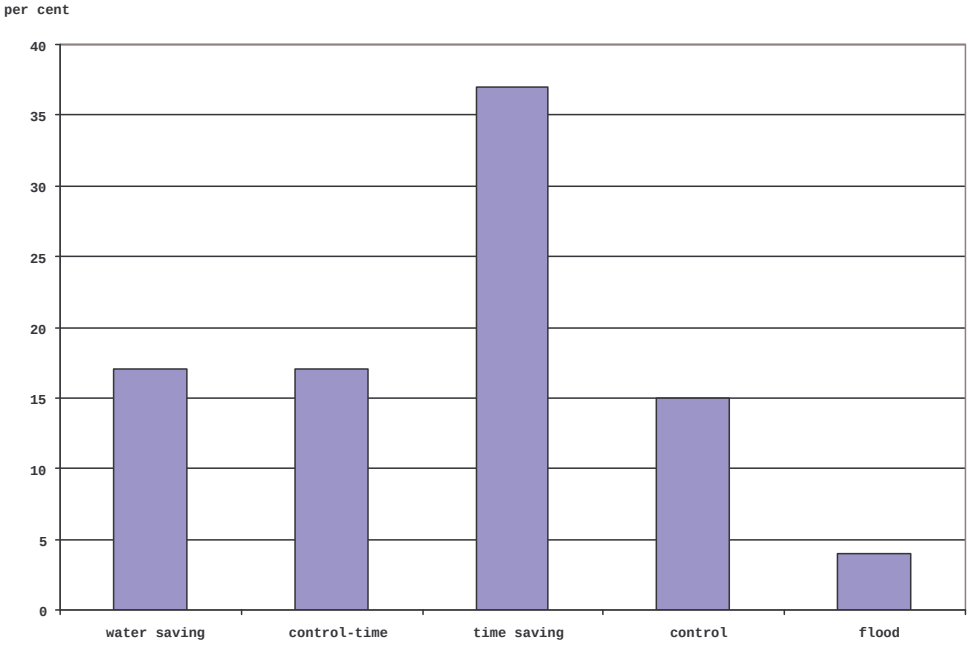

Figure 18: Irrigation systems segments and use of irrigation consultants and services

Soil moisture monitoring segments

Interviews with fruit growers in the first stage of this study revealed that only fruit growers with micro-irrigation and who have immediate access to water (*ie* can water on demand) are in a position to take full advantage of monitoring to schedule irrigations.

Growers who only have bay or furrow flood irrigation do not have sufficient control over the delivery of irrigation water in the orchard to take full advantage of monitoring. These growers might use monitoring to help manage a tree health problem caused by a high water table or salinity.

Growers with under-tree knocker sprinklers may use monitoring to help establish appropriate irrigation frequencies and run times to save pumping costs and to manage tree health problems but again are unable to take full advantage of monitoring because they generally cannot irrigate on demand. Similarly, growers with micro-irrigation who cannot irrigate on demand are limited to using monitoring to help establish irrigation frequencies and run times, and to investigate tree health problems.

Consequently, for this part of the study, fruit growers were classified into segments for soil moisture monitoring on the basis of their type of irrigation system and whether they could irrigate on demand. Again, 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. A 'scree' test indicated that three segments were present in the sample (Aldenderfer and Blashfield 1984).

The formation of the segments is illustrated in figure 19. The sample was initially partitioned into two groups depending on whether or not growers could irrigate on demand. One segment consisted of those growers with micro-irrigation who could irrigate on demand. These are growers who would be able to use monitoring to adjust their irrigation schedules on a daily basis. This 'micro scheduling' segment represented 50 per cent of growers in the sample.

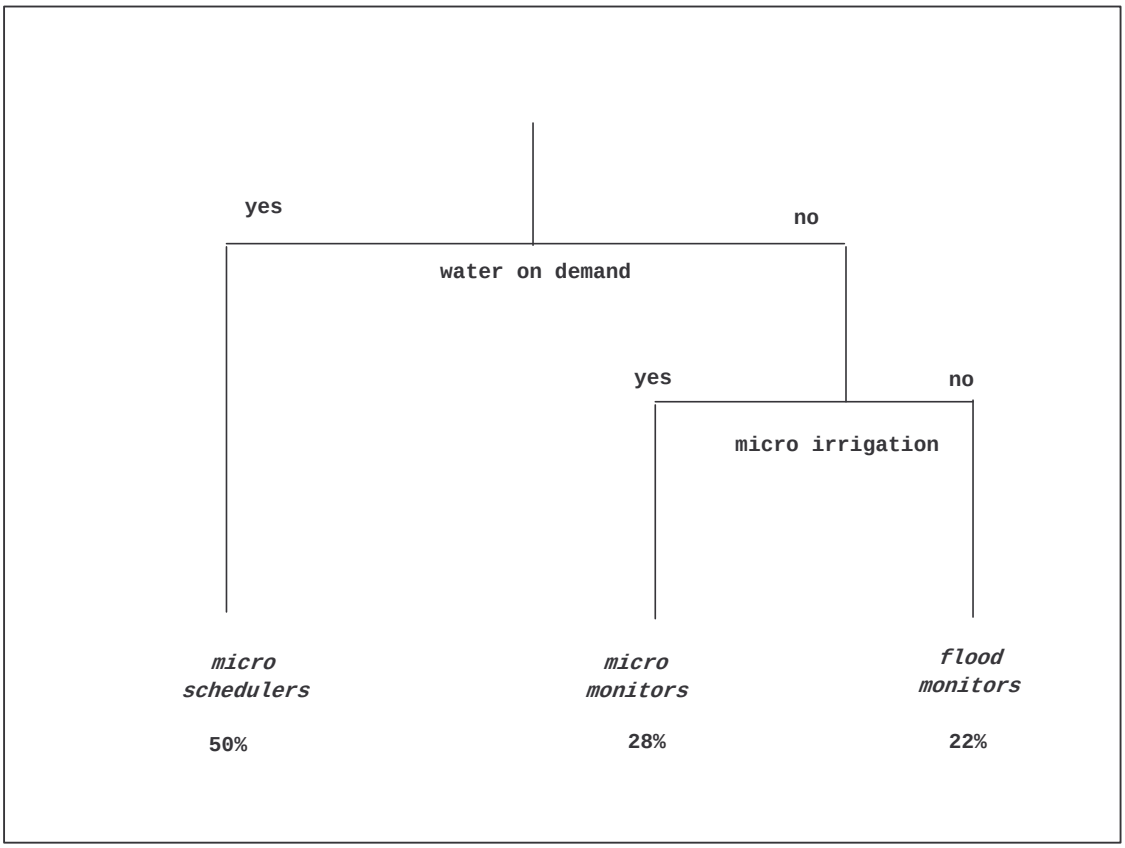

Figure 19: Soil moisture monitoring segments

Growers who could not irrigate on demand were sub-divided into two segments depending on their irrigation system. One segment consisted of 'flood monitors' who represented 22 percent of growers. The other segment, 'micro monitors', represent 28 percent of growers in the sample. These growers would be limited to using monitoring to help establish irrigation frequencies and run times, and to investigate tree health problems.

In figure 20 the proportion of growers in each segment who have tried soil moisture monitoring is shown. As expected, the frequency of adoption of soil moisture monitoring is highest among growers with micro-irrigation who can irrigate on demand. Also, as expected, the frequency of adoption of soil moisture monitoring is lowest among growers with flood irrigation.[13]

Nearly 50 per cent of the growers in the 'micro scheduling' segment have tried soil moisture monitoring. Approximately 40 per cent of these did so because they either had a problem with vigour, high watertables or salinity, or because they are growing dwarf rootstocks.

The other 60 per cent of the growers in this segment use soil moisture monitoring to help schedule their first irrigation, to check irrigation performance or to schedule their irrigations. These growers have significantly larger orchards than those growers who have not tried monitoring (71 hectares compared to 21 hectares)[14]. The growers in this segment who have tried monitoring are also much more likely to have programmable timers than growers who have not (49 per cent compared to 25 per cent)[15]. One explanation for these results may be that growers with larger orchards use soil moisture monitoring to periodically check irrigation performance and reprogram their irrigation timers accordingly.

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[13] The overall rate of adoption of soil moisture monitoring by district appears consistent with the results presented by (Boland 1998).
[14] $F_{1,99}=6.3$, $p=0.01$
[15] $\chi^2=6.9$, $p=0.01$

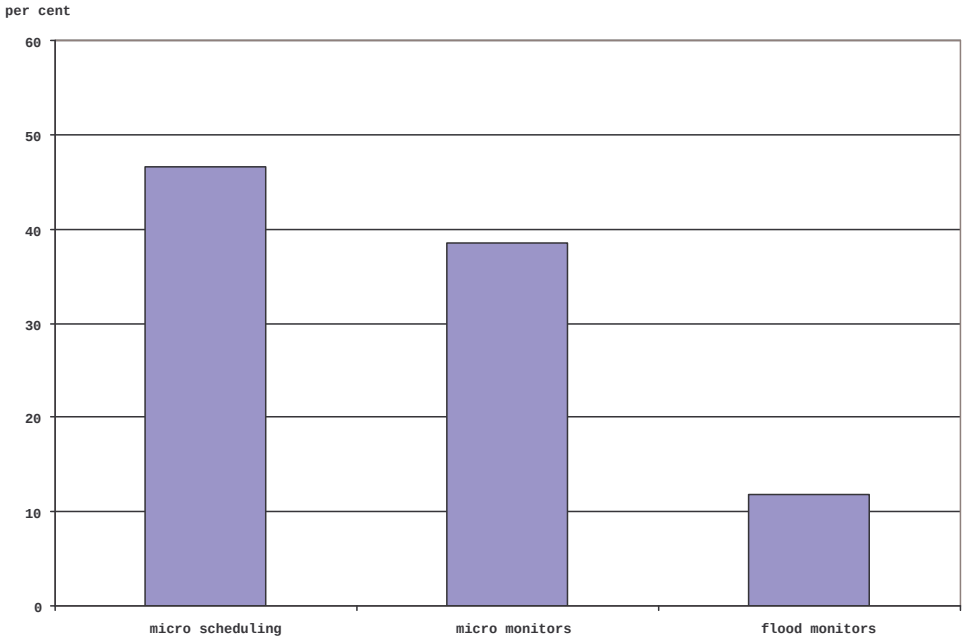

Figure 20: Segments and adoption of soil moisture monitoring

Six per cent of the growers in this segment who have tried monitoring did not find it helpful. Four per cent of growers in this segment have automated their irrigation by linking their soil moisture monitoring equipment to their irrigation system.

Almost 40 per cent of growers in the 'micro monitors' segment have tried soil moisture monitoring. Of these, 20 per cent adopted monitoring because they had a problem either with tree vigour, watertables or salinity, or they had planted dwarf rootstocks.

Nearly 36 per cent of those growers in this segment who had tried monitoring found that it was not much use or took up too much time. For the remaining 44 per cent of growers in the segment that used monitoring it appears that most growers were using it to help decide when to start the irrigation season. Some growers with larger orchards were also using monitoring in a few blocks to periodically check irrigation performance.[16]

Less than ten per cent of growers in the 'flood monitor' segment have tried soil moisture monitoring.

Conclusions

The results from the survey of fruit growers indicate the major forces driving the adoption of micro-irrigation are:

- The shift to trellis and closer planting techniques;
- A need to reduce time spent irrigating; and
- A need to increase flexibility in managing irrigation, spraying and picking activities in the orchard.

These findings lead to the conclusion that the area under flood irrigation will continue to decline as growers redevelop orchards and as the demands on grower's time

[16] $F_{1,44}=5.5$, $p=0.02$

increase, especially in periods when activities such as irrigation, spraying and picking coincide. These findings also suggest the rate of adoption of micro-irrigation may be influenced indirectly through activities that promote trellising and closer planting techniques to growers who are redeveloping their orchards.

Increasing water use efficiency was not identified by most fruit growers as a factor in the adoption of micro-irrigation. Less than 20 per cent of growers indicated they adopted micro-irrigation because of problems with limited water supplies, high water tables, salinity or because micro-irrigation best suits their soils or topography. These findings suggest it is unlikely that extension activities aimed at promoting an increase in water use efficiency will have a substantial influence on the rate of adoption of micro-irrigation.

The results from the survey of fruit growers indicate the adoption of soil moisture monitoring is strongly associated with:

- Problems with high water tables, salinity or tree vigour;
- Planting of dwarf rootstocks ; and
- A need on larger orchards to check irrigation performance.

The keys to successfully adopting soil moisture monitoring are the use of micro-irrigation and access to irrigation water on demand. Growers with flood irrigation appear to derive little benefit from soil moisture monitoring because they do not have the flexibility necessary to adjust their irrigation scheduling. Growers with micro-irrigation who cannot water on demand also experience difficulties with using soil moisture monitoring to schedule because they are unable to adjust ordering of irrigation water appropriately.

These findings lead to the conclusion that growers who do not have access to water on demand, or who flood irrigate, will adopt soil moisture monitoring but not to regularly schedule irrigations. These growers use monitoring to resolve problems with tree health or tree vigour, or to help determine the timing of the first irrigation of the season.

The findings also suggest that many growers who have micro-irrigation and do have access to water on demand also use monitoring to resolve problems with tree health or tree vigour. However, it appears that growers with larger orchards who have micro-irrigation and access to water on demand may adopt monitoring to check on irrigation performance. This suggests there may be an opportunity to actively promote monitoring among growers with larger orchards.

Increasing water use efficiency was not identified by fruit growers as a factor in the adoption of soil moisture monitoring. This suggests it is unlikely that extension activities aimed at promoting an increase in water use efficiency will have a substantial influence on the rate of adoption of soil moisture monitoring.

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Appendix A

Survey Questionnaire

Soil Monitoring,

Irrigation Scheduling and Fruit Production

PART THREE

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Soil Monitoring, Irrigation Scheduling and Fruit Production

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29 January, 2002

Executive Summary

In this study we used market research data from two previous studies to develop extension strategies for irrigation management of stone and pome fruit. The results of these studies indicated that efficient water use in horticulture might be promoted by a variety of extension strategies that would facilitate the adoption of micro-irrigation and soil moisture monitoring by fruit growers. However, it is important to recognise efficient water use is not a key factor influencing the adoption of micro-irrigation in most instances. This means that efforts to promote the adoption of micro-irrigation by highlighting gains in water use efficiency are unlikely to be effective.

Only a small proportion of growers are motivated to adopt micro-irrigation by a need to reduce water use because of problems with scarce water supplies, salinity, high water tables or excessive tree vigour. For most growers the key factors influencing the adopting micro-irrigation are a need to reduce time spent irrigating, a desire to increase flexibility in managing irrigation, spray and harvesting activities, and a desire to increase productivity and profitability by redeveloping orchards to closer planting or trellis designs.

A workshop with relevant extension staff from the Department of Natural Resources and Environment was organised to review and interpret the results of the market research and to develop draft extension strategies. Validation interviews were then undertaken with growers to confirm that the extension strategies developed were relevant.

Based on the outcomes of the workshop and the results of the earlier qualitative and quantitative studies we recommend:

- A strategy is developed to facilitate the change from flood to micro-irrigation by providing advice and assistance on the choice and design of micro-irrigation systems.

- A strategy is developed to facilitate the change from flood to micro-irrigation by providing advice and assistance on the management of micro-irrigation systems

when they are first installed. In developing this strategy the different information needs of growers will vary. Growers that are converting established orchards will have different needs compared to growers that are redeveloping their orchards.

- That strategies to facilitate the change from flood to micro-irrigation include recommendations to growers to use soil moisture monitoring to help establish irrigation schedules for newly installed micro-irrigation systems.

- A strategy is developed to provide assistance to growers in choosing and installing soil moisture monitoring equipment and in interpreting monitoring data.

- A strategy is developed to promote the use of soil moisture monitoring as a technique for managing problems such as high water tables or excessive tree vigour.

- A strategy is developed for promoting the use of soil moisture monitoring as a technique for checking the effectiveness of irrigation schedules.

Where possible strategies for promoting the adoption of soil moisture monitoring should be directed initially toward growers with relatively large orchards and growers with micro-irrigation and water on demand. Also, where possible, consideration should be given to involving suppliers of irrigation equipment and services in the development and implementation of these strategies.

Acknowledgments

The Victorian Department of Natural Resources and Environment funded this study. We would like to thank the staff at DNRE Tatura for their assistance and support. We are especially grateful to Chris Linehan for his time and assistance.

We are indebted to the Department staff who participated in the extension workshop and the fruit growers who participated in the study by being kind enough to grant us interviews.

All errors and omissions remain the responsibility of the authors.

Table of Contents

Soil Monitoring, Irrigation Scheduling and Fruit Production

Introduction

In previous reports (Kaine and Bewsell, 1999 and Kaine and Bewsell, 2000) we described the results from qualitative and quantitative studies into the adoption of micro-irrigation and soil moisture monitoring in the stone and pome fruit industry. The results of these studies were used to develop extension strategies and recommendations for promoting the adoption of micro-irrigation and soil moisture monitoring. These strategies and recommendations are the subject of this report.

The qualitative study revealed that growers' propensity to adopt micro-irrigation systems depended on a number of key factors. These were:

- A desire on the part of the grower to reduce the amount of time spent irrigating and to increase their managerial flexibility in the orchard. Flood irrigation systems are labour intensive, as they require regular surveillance when operating and bays need to be changed manually in the orchard. Micro-irrigation systems require minimal surveillance they operate at fixed flow rates and can be managed using remote control valves. Also, as flood systems wet the entire orchard floor growers are unable to spray or harvest while flood irrigating. This problem is avoided with micro-irrigation systems as these systems only wet the treeline.

- The redevelopment of orchards to closer planting or trellis designs. The layout of trees in closer planting or trellis designs and use of mounds in these designs renders flood irrigation (including knocker sprinklers) impractical.

- A desire on the part of the grower to reduce the amount of irrigation water used in order to maximise production from limited water supplies, or to overcome problems with tree health caused by salinity or a high water table.

The qualitative study also revealed that the propensity of growers' to adopt soil moisture monitoring depended on the following factors:

- A desire on the part of the grower to reduce the amount of irrigation water used in order to maximise production from limited water supplies, to manage problems with excessive vigour or dwarf rootstocks, or to overcome problems with tree health caused by salinity or a high water table.

- Access to continuously available irrigation water (water on demand).

- Installation of a micro-irrigation system.

In the quantitative study we classified stone and pome fruit growers in the Goulburn and Murray Valleys and the Tumut-Batlow district into five segments based on the whether they had installed micro-irrigation and their reasons for installing micro-irrigation. The segments, which are summarised in table 1, were as follows.

- We described the first segment as the 'control and time redeveloper' segment. This segment consisted of growers whose main reasons for installing micro-irrigation were to save time and labour irrigating, to increase their flexibility in terms of harvesting and spraying fruit while irrigating, and who had redeveloped their orchards to a closer planting or trellis design. The growers in this segment represented approximately 23 per cent of respondents.

- The second segment consisted of growers whose main reasons for installing micro-irrigation were to save time and labour irrigating and to increase their flexibility in terms of picking and spraying fruit while irrigating. The growers in this 'time saving converter' segment represented approximately 24 per cent of respondents.

- The growers in the third segment, the 'water saving' segment, were growers who had installed micro-irrigation in order to manage limited water supplies, problems with salinity, water tables or water deliveries, or because micro-irrigation best suited their soils or topography. This segment represented 17 per cent of the sample. Approximately half of the growers in this segment were from Batlow and

Table 1: Summary of irrigation system segments.

	Control & time redevelopers	**Time saving converters**	**Water saving irrigators**	**Control redevelopers**	**Flood irrigators**
Replanting the orchard	Yes	No	No	Yes	No
Need to save time irrigating and increase flexibility for harvesting/spraying	Yes	Yes	No	No	No
Scarce water, or problems with water tables or salinity	No	No	Yes	No	No

Tumut. Less than 10 per cent of growers from the Goulburn and Murray Valleys were in this segment.

- The fourth segment consisted of fruit growers who installed micro-irrigation mainly because they were redeveloping their orchards to closer planting designs or trellises. The growers in this 'control redeveloper' segment represented approximately 15 per cent of respondents.

- The growers in the fifth segment were growers who only had some form of flood irrigation (bay, furrow or under-tree knocker sprinklers). These growers represented 22 per cent of respondents.

In the quantitative study we also classified stone and pome fruit growers in the Goulburn and Murray Valleys and the Tumut-Batlow district into three segments with respect to soil moisture monitoring. The segments, which are summarised in table 2, were as follows.

- One segment consisted of growers with micro-irrigation who could irrigate on demand. These growers are in a position to use objective soil moisture monitoring to adjust their irrigation schedules on a daily basis. This 'micro scheduling' segment represented 50 per cent of growers in the sample.

- The second monitoring segment, 'micro monitors', represented 28 percent of respondents. These growers had installed micro-irrigation but did not have water on demand. Consequently, the growers in this segment are unable to routinely use monitoring to schedule irrigations on a daily basis. These growers would tend to use monitoring periodically to assist in establish irrigation frequencies and run times over the irrigation season, and to investigate tree health problems.

- The third segment, 'flood monitors', represented 22 percent of growers. These growers could not irrigate on demand and were flood irrigating and, consequently, these growers were particularly limited in their ability to use soil moisture monitoring.

Table 2: Summary of soil moisture monitoring segments.

	Micro schedulers	Micro monitors	Flood monitors
Water on demand[1]	Yes	No	No
Micro irrigation installed	Yes	Yes	No

Notes:

1. Water on demand was defined as being able to access water within 24 hours. For example a grower might have an on-farm storage, pump directly from a river, be able to order and obtain water within 24 hours, or have a standing monthly order.

Water on demand was defined as being able to access water within 24 hours. For example a grower might have an on-farm storage, pump directly from a river, be able to order and obtain water within 24 hours, or have a standing monthly order.

We found that most fruit growers did not identify improving water use efficiency as a key reason for adopting micro-irrigation. Less than 20 per cent of growers indicated they adopted micro-irrigation to save water because of problems with limited water supplies, high water tables, salinity or because micro-irrigation best suited the soils or topography of their orchards. This suggests that extension activities that promote the benefits of increased water use efficiency that result from using micro-irrigation are unlikely to be effective in increasing the adoption of these systems.

The results from the survey indicated that the area under flood irrigation should decline over time as growers redevelop orchards and as the demands on grower's time increase, especially in periods when activities such as irrigation, spraying and picking coincide. This suggests the rate of adoption of micro-irrigation may be indirectly influenced through extension activities that promote trellising and closer planting designs.

We also found that water use efficiency per se was not a factor for most growers in the adoption of soil moisture monitoring. Some growers were using soil moisture monitoring to reduce application rates (water use per hectare) in order to cope with limited water supplies, problems with vigour or high water tables. This suggests that extension activities that promote the benefits of increased water use efficiency that result from using quantitative soil moisture monitoring are unlikely to be effective in increasing the adoption of quantitative monitoring systems.

Based on the survey information it appears that soil moisture monitoring may be promoted to growers who do not have access to water on demand, or who flood irrigate, as a technique to assist in determining the timing of the first irrigation of the season. Soil moisture monitoring may also be promoted to these growers as a technique to assist resolving problems with tree health or tree vigour.

The results of the survey did indicate that growers with larger orchards who have micro-irrigation and access to water on demand were more likely to adopt soil moisture monitoring as a technique to check on irrigation performance. This suggests there may be an opportunity to actively promote soil moisture monitoring among growers with larger orchards.

Irrigation segments and extension strategies

A facilitated workshop was used to develop extension strategies and priorities using the information and perspectives gained from the qualitative and quantitative studies and the knowledge and experience of Department staff involved in stone and pome fruit extension. Draft strategies were developed for an extension program using the program logic approach (Mayeske, 1994).

On the basis of consumer behaviour theory, we took the view in developing the extension strategies that the strategies would target growers who were dissatisfied with their irrigation management for some reason and would, therefore, be likely to be motivated to change their irrigation management. Consequently, the starting point in the strategy formulation process was identifying the range of problems that could potentially create dissatisfaction on the part of growers with respect to irrigation management.

Following Mayeske's (1994) procedure the factors that could potentially cause dissatisfaction with irrigation management for growers in each irrigation segment were categorised into problem trees. Solutions to these potential problems were then developed. These problem and solution trees are summarised in appendix A.

A number of factors were identified that might cause dissatisfaction with irrigation management for growers with flood or micro-irrigation. The response to most problems with flood irrigation, such as a shortage of labour or high water tables, is to install micro-irrigation. Consequently, the problems that were identified in the workshop concern difficulties either in converting from flood to micro-irrigation or difficulties in managing micro-irrigation systems once installed. As a result, many of

the factors are not segment-specific and have the potential to occur in each irrigation segment. The factors were classified into the following broad categories:

- Managing change. Growers changing from flood irrigation could experience problems in managing micro-irrigation of young trees if they were redeveloping their orchards or if they were converting established trees to micro-irrigation. There is also potential for problems to occur with poor irrigation designs and with planning the development of the orchard from flood to micro-irrigation systems.
- Technical issues. This category covers problems such as excessive tree vigour, hares chewing lines, post harvest maintenance and soil acidity. It also includes problems with pump failures, blockages of filters and lines, and power supplies.
- Infrastructure issues. Growers may experience difficulties with irrigation management as a result of poor water quality or delays in water deliveries.
- Retraining. For some growers there may be a need to retrain staff to manage micro-irrigation systems.

The workshop participants agreed that retraining was not a major issue for most growers. The participants also agreed that, in terms of an extension program, the role for the Department in terms of infrastructure issues was extremely limited. Infrastructure issues were seen to be the responsibility of the regional water authority.

The participants in the workshop believed that Departmental extension programs could be directed at assisting growers to manage problems with changing from flood to micro-irrigation and assisting growers with managing the technical problems that can arise with micro-irrigation. The participants believed that extension strategies addressing these problems could be tailored to the needs of growers in each segment by, for example:

- Providing information on managing young trees under micro-irrigation for growers in both of the redeveloper segments. This information could include recommendations to use soil moisture monitoring to help establish irrigation schedules for newly installed micro-irrigation systems.

- Providing information on managing established trees under micro-irrigation for growers in the water saving segments and the time saving converter segment. This information could also include recommendations and advice about using soil moisture monitoring to help establish irrigation schedules for newly installed systems.
- Work with irrigation designers to overcome any micro-irrigation system design problems especially for flood irrigators who are shifting into one of the redeveloper segments or the time saving segment.
- Provide information for growers in all segments on technical issues (eg excessive tree vigour, hares chewing lines etc), particularly emphasising the links between fruit quality, vigour and irrigation management. Again, this could include advice about using soil moisture monitoring to help establish appropriate irrigation schedules.

The extension strategies for each segment are summarised in table 3.

The extension strategies were validated by conducting a final round of interviews with growers from the 'control and time redevelopers', 'time saving converters' 'water saving' and 'control redevelopers' segments in the Goulburn Valley.

All the growers that were interviewed indicated that they had experienced some initial problems with micro-irrigation. The growers also indicated they had overcome these problems within a season or two through trial and error learning and discussions with other growers and with irrigation equipment suppliers. None of the growers indicated that they had experienced any long-term problems and all were satisfied with their current irrigation system and management. These results are consistent with the views expressed by the growers we interviewed in the first stage of the study. One or two growers did express some dissatisfaction with the lack of information provided by the Department.

Table 3: Extension strategies developed for irrigation system segments.

Extension strategies	Managing young trees	Managing established trees	Working with designers to ensure good system design	Technical advice[1]
Control & time redevelopers	X		X	X
Time saving converters		X	X	X
Water saving irrigators		X	X	X
Control redevelopers	X		X	X
Flood irrigators	Target when converting to one the segments above			

Notes:

1. Technical advice covers issues such as excessive tree vigour, hares chewing lines etc, particularly emphasising the links between fruit quality, vigour and irrigation management.

For example, from the ‘control and time redeveloper’ segment:

> *Fred and his family started converting the property to micro-irrigation in the early 80’s. As they redeveloped and as money permitted they have converted the whole property and been able to save time and increase their flexibility. Working out how to run the system was trial and error, however they had no real problems. Fred is concerned that DNRE does not do any trial work in this area to find out which system suits which soil etc.*
> *Recently they have begun leasing a nearby property that is under an old drip irrigation system. This has prompted them to investigate drip irrigation as an alternative to microjets. They are planning to try a block next season and evaluate how the system goes.*

Joe is a grower in the ‘time saver converter’ segment:

> *Joe initially tried micro-irrigation when he redeveloped a block some ten years ago. He found the system worked well particularly in terms of time saving and so converted the remaining blocks on the property to micro to take advantage of this. He did have some problems with micro at the start. He found that the trees did not do very well, with poor fruit size and vigour especially in his pear blocks. After talking to an older grower he realised he wasn’t giving them the water they needed. He now uses more water than he had been told when he first put the system in, especially on pears. The only problem he has now is with foxes chewing the micro tube.*

From the ‘water saving’ segment:

> *George and his family converted their property to micro because their property is quite sandy in parts and they had been losing some stone fruit trees with floods and wet winters. There were also time and management benefits to installing the micro system. They converted their property in stages with the help of their irrigation supplier. In hindsight, although it does the job they may have increased the capacity of the system slightly.*

From the ‘control redeveloper’ segment:

> *Warren installed micro on his new trellis plantings when he started developing the property. Unlike many on the district he installed drip irrigation and says it’s the best system he knows. He has since installed some microjets but prefers the drip irrigation. He had no real problems with the micro-irrigation and is currently working with a drip tape manufacturer to trial some new in-line drippers on his property.*

These responses suggest that there may be a role for the Department to conduct extension programs that are intended to facilitate the change from flood to micro-

irrigation by providing advice and assistance, perhaps in conjunction with suppliers of irrigation equipment, on the choice and design of micro-irrigation systems. There may also be a role for extension programs, again in conjunction with equipment suppliers, to provide advice and assistance on the management of these systems when they are first installed. This assistance could include recommendations to use soil moisture monitoring to help establish irrigation schedules for newly installed micro-irrigation systems.

Soil moisture monitoring segments and extension strategies

The main factors that were identified in the workshop that could potentially cause dissatisfaction for growers in the micro scheduler and micro monitor segments were technical problems. For example, growers might experience problems with salinity or high water tables, excessive tree vigour or dwarf rootstocks, which were not being fully resolved with the use of soil moisture monitoring. Problems trees developed are outlined in Appendix B.

The extension strategy that was developed to respond to these problems was to provide growers with advice and assistance in siting and calibrating soil moisture monitoring and in utilising monitoring information more effectively. Solution trees are outlined in Appendix B.

Taken together with the irrigation extension strategies described earlier, this suggests the Department could promote soil moisture monitoring to fruit growers by:

- Promoting soil moisture monitoring as a technique for developing irrigation schedules for newly installed micro-irrigation systems.
- Promoting soil moisture monitoring as a technique for checking irrigation performance, especially among larger growers.
- Promoting soil moisture monitoring as a technique for managing problems with salinity or water tables, excessive tree vigour or dwarf rootstocks.
- Providing advice and assistance in siting and calibrating soil moisture monitoring and in utilising monitoring information more effectively.

The extension strategies for each monitoring segment are summarised in table 4.

These extension strategies were validated with the growers that we interviewed to validate the extension strategies for irrigation systems. Two of the growers we interviewed were using soil moisture monitoring. Both of these growers were from the 'micro scheduling' segment. One grower with a relatively large orchard was relying on a consultant to provide advice on irrigation management.

> *George uses a consultant to help schedule his irrigations. The consultant has a neutron probe and reads a number of sites in the orchard once a week. He provides George with a report and suggested run times. George believes he was over-watering before as he has found that he is now using less water than before. George is at the end of a channel so put in a holding dam a number of years ago to counteract the problems they had getting water when they wanted it.*

The second grower uses soil moisture monitoring to check his irrigation scheduling.

> *Warren uses crop factors as the basis for scheduling his irrigations. He has tensiometers installed in several blocks as a way of checking on the irrigations. He is able to water on demand as although he is on a spur channel it always holds water. This means he can pump when he likes as he only uses small amounts of water at a time.*

Other growers we interviewed were from the 'micro monitor' segment and so did not have water on demand. Most of these growers relied on experience and used a shovel as a check to see how their irrigations were going. Few though could see any benefits to adopting soil moisture monitoring. Consider the following example:

> *Joe has thought about using soil moisture monitoring. However he is at the end of a spur channel and cannot get water on demand. Under these circumstances he does not see any benefits to using soil moisture monitoring. The calender, an eye on the weather and the occasional check with the shovel provides him with all the information he needs.*

Table 4: Extension strategies developed for the soil moisture monitoring segments.

Extension strategies	Using monitoring for developing schedules[1]	Using monitoring for predicting schedules[2]	Promote monitoring as a check for irrigation performance	Tool for managing problems (eg water tables, salinity)	Siting and calibrating advice
Micro schedulers	X		X	X	X
Micro monitors		X	X	X	X
Flood monitors		Target when converting to one of the above segments			

Notes:

1. Micro schedulers will be able to schedule on a daily basis if necessary given they have water on demand.

2. Developing schedules for micro monitors will have more of a predictive element as these growers do not have water on demand.

These responses suggest that there may be a role for extension programs in promoting the use of soil moisture monitoring generally as a technique for checking the effectiveness of irrigation schedules.

Recommendations

Based on the outcomes of the workshop and the results of the earlier qualitative and quantitative studies we recommend:

- A strategy is developed to facilitate the change from flood to micro-irrigation by providing advice and assistance on the choice and design of micro-irrigation systems. In developing this strategy consideration should be given to the possibility of pursuing this strategy in conjunction with suppliers of irrigation equipment and services.

- A strategy is developed to facilitate the change from flood to micro-irrigation by providing advice and assistance on the management of micro-irrigation systems when they are first installed. In developing this strategy the different information needs of growers will vary. Growers that are converting established orchards will have different needs compared to growers that are redeveloping their orchards. In developing this strategy consideration should be given to involving suppliers of irrigation equipment and services in the implementation of the strategy.

- That strategies to facilitate the change from flood to micro-irrigation include recommendations to growers to use soil moisture monitoring to help establish irrigation schedules for newly installed micro-irrigation systems.

- A strategy is developed to provide assistance to growers in choosing and installing soil moisture monitoring equipment and in interpreting monitoring data.

- A strategy is developed to promote the use of soil moisture monitoring as a technique for managing problems such as high water tables or excessive tree vigour.

- A strategy is developed for promoting the use of soil moisture monitoring as a technique for checking the effectiveness of irrigation schedules.

Where possible strategies for promoting the adoption of soil moisture monitoring should be directed initially toward growers with relatively large orchards and growers with micro-irrigation and water on demand.

Conclusion

The results of this study suggest that efficient water use in horticulture can be promoted by a variety of extension strategies that will facilitate the adoption of micro-irrigation and soil moisture monitoring by fruit growers. However, it is important to recognise efficient water use is not a key factor influencing the adoption of micro-irrigation. This means that efforts to promote the adoption of micro-irrigation by highlighting gains in water use efficiency are unlikely to be effective.

Some growers are motivated to adopt micro-irrigation by a need to reduce water use because of problems with scarce water supplies, salinity, high water tables or excessive tree vigour. However, for most growers the key factors influencing the adopting micro-irrigation are a need to reduce time spent irrigating, a desire to increase flexibility in managing irrigation, spray and harvesting activities, and a desire to increase productivity and profitability by redeveloping orchards to closer planting or trellis designs. This means the adoption of micro–irrigation is largely determined by long term changes in the circumstances of growers such as changes in family composition and enterprise expansion. Consequently, the role of extension in promoting the adoption of micro-irrigation is to facilitate the process of changing from flood to micro-irrigation once circumstances have prompted growers' to make the change.

Some growers were motivated to adopt soil moisture monitoring by a need to reduce water use because of problems with scarce water supplies, salinity, high water tables or excessive tree vigour. Other growers, generally those with larger orchards, tended to use monitoring to check irrigation performance. Generally speaking however, interest among growers in soil moisture monitoring is limited because increasing water use efficiency is not a key concern for the majority of growers. Furthermore, only 50 per cent of growers are in a position to take full advantage of soil moisture monitoring as only these growers have micro-irrigation and access to water on demand.

We concluded that the return to efforts to promote the adoption of soil moisture monitoring by highlighting gains in water use efficiency are likely to be limited. There may be some value to promoting soil moisture monitoring equipment as a means of facilitating the change from flood to micro-irrigation. However, we note that most growers appeared capable of establishing irrigation schedules for newly installed micro-irrigation systems without much difficulty.

In our view, interest in soil moisture monitoring will be greatest among those growers experiencing problems with scarce water supplies, high water tables or excessive tree vigour.

References

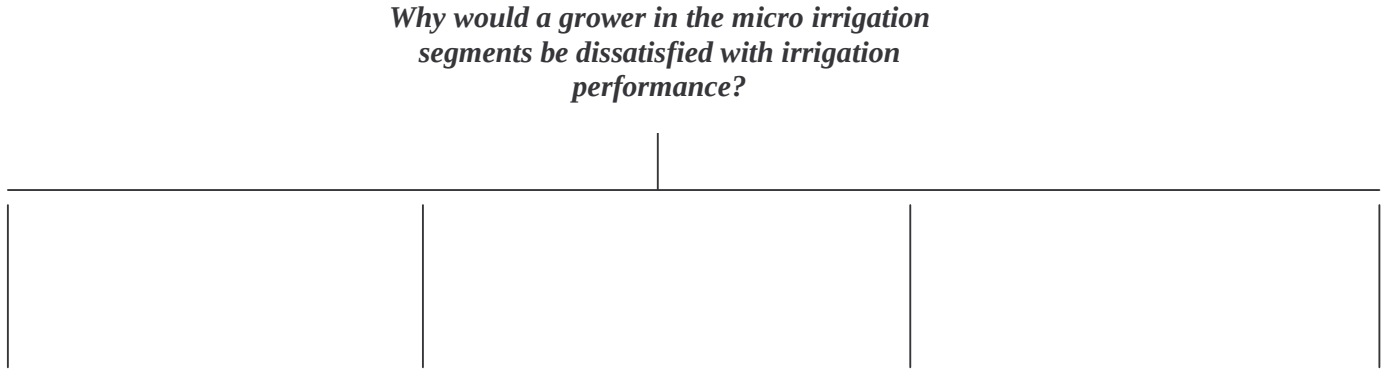
Kaine,G. and Bewsell, D. (1999). Soil Monitoring, Irrigation Scheduling and Fruit Production, Part One. Armidale, N.S.W., School of Marketing and Management, University of New England.

Kaine,G. and Bewsell, D. (2000). Soil Monitoring, Irrigation Scheduling and Fruit Production, Part Two. Armidale, N.S.W., School of Marketing and Management, University of New England.

Mayeske, G. W. (1994). *Life Cycle Program Management and Evaluation: An Heuristic Approach*, United States Department of Agriculture Extension Service, Washington.

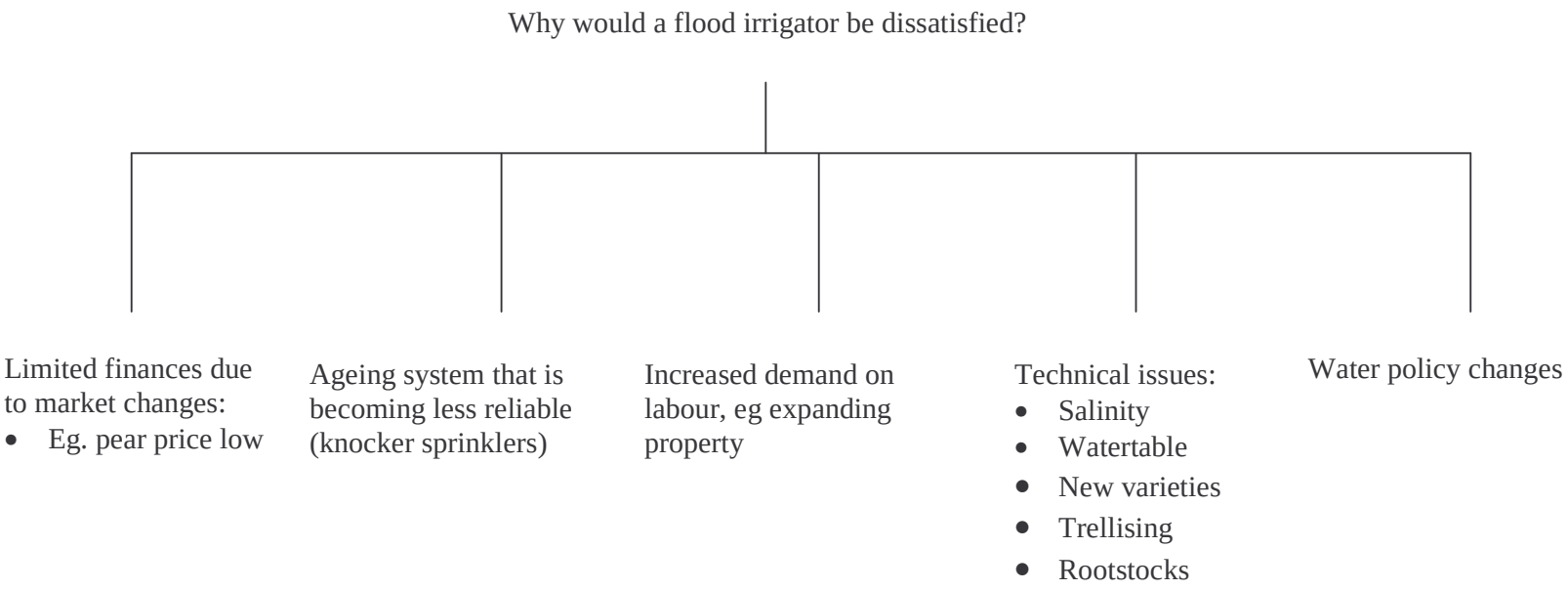
Appendix A

Micro irrigated problem tree



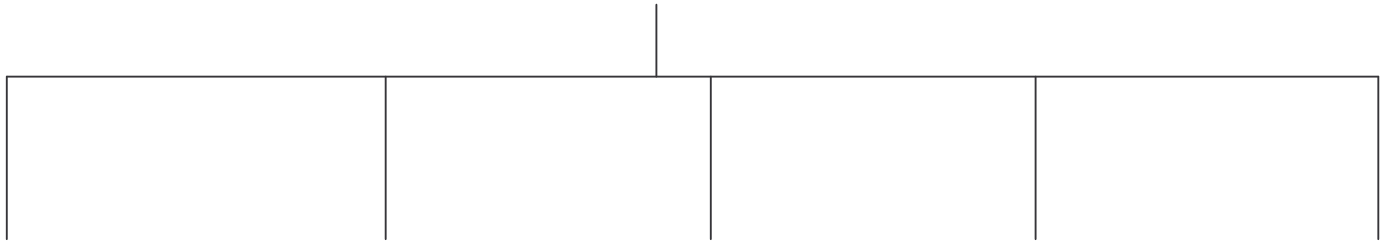
* Denotes issue with large impact on growers

Flood irrigation problem tree



Problem tree for conversion to micro irrigation

What problems would a flood irrigator have changing to micro irrigation?



Finance:

- Increased number of trees
- Trellising
- Irrigation system

Knowledge/skills:

- Choice of system
- Management
- Integration of irrigation/pruning etc

Information gaps:

- Run times
- Soil water capacity
- Rootstocks

Planning the conversion

Water issues:

- Water availability
- Water quality

Solution trees for micro irrigation (1)

Problems with installing micro irrigation:

- Problems with the pump/blockages/filters/power
- Design problems
- Managing the change
- Scheduling

Provide information on managing trees under micro irrigation

Role for extension

Systems designed correctly

Irrigation designers problem – possibly some role for extension with designers

Solution trees for micro irrigation (2)

Retraining:

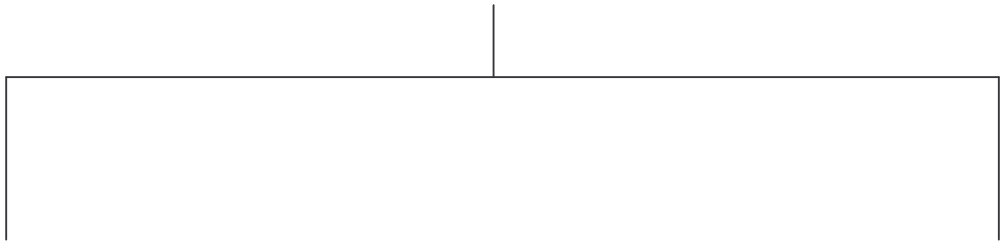
- Need to train staff or grower to manage the new system

Agreed not big issue for growers

Solution trees for micro irrigation (3)

Technical issues:

- Excessive tree vigour
- Hares chewing lines
- Post harvest maintenance
- Considerations for dwarfing rootstocks in apples
- Soil acidity



Information provided for growers particularly emphasising the links between fruit quality, vigour and irrigation

Role for extension to provide this information

Resourcing – making the information available to growers

Part of extension role to plan for this

Solution trees for micro irrigation (4)

Infrastructure problems:

- Poor water quality
- Water not able to be constantly accessed

Provide information on how to deal with these issues

Water authority issue

Improve water quality

Water authority issue

Provide access to water on demand

Water authority issue

Solution trees for converting to micro irrigation (1)

Finance:

- Increased number of trees
- Trellising
- Irrigation system

Not within scope of extension

Solution trees for converting to micro irrigation (2)

Knowledge/skills:
1. Choice of system
2. Management
3. Integration of irrigation/pruning etc

Provide information on:
Systems
Management etc

Extension role

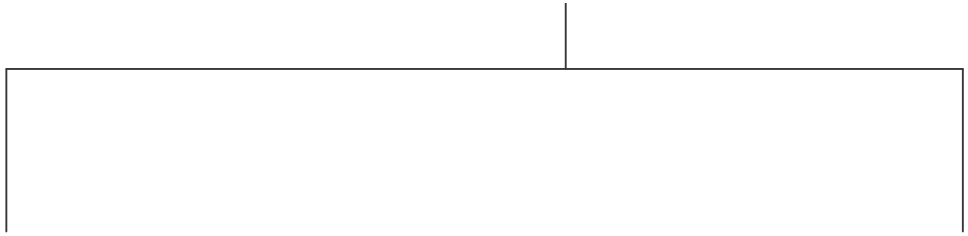
Resourcing – making the information available to growers

Part of extension role to plan for this

Solution trees for converting to micro irrigation (3)

Information gaps:

- Run times
- Soil water capacity
- Rootstocks



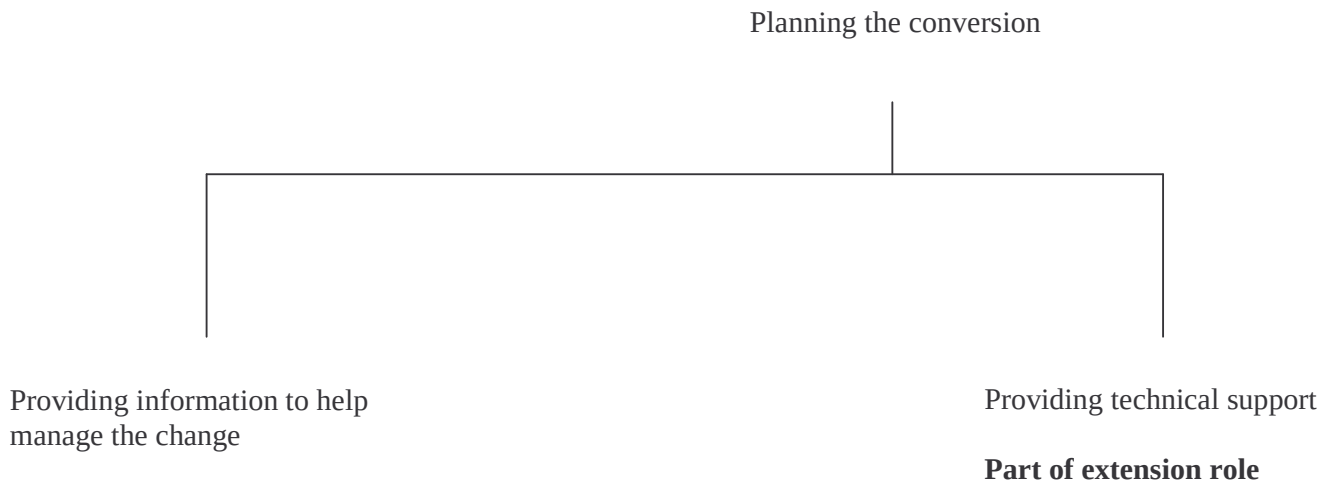
Provide information on the above

Extension role

Resourcing – making the information available to growers

Part of extension role to plan for this

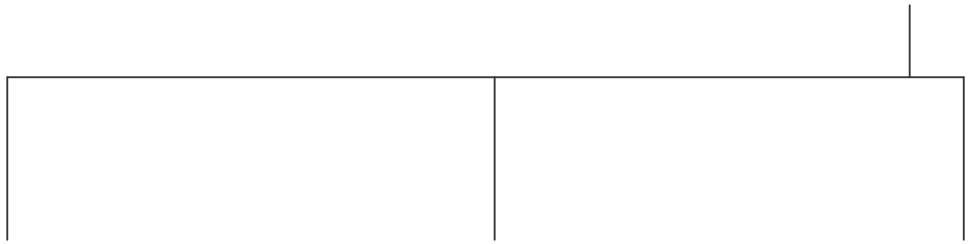
Solution trees for converting to micro irrigation (4)



Solution trees for converting to micro irrigation (5)

Water issues:

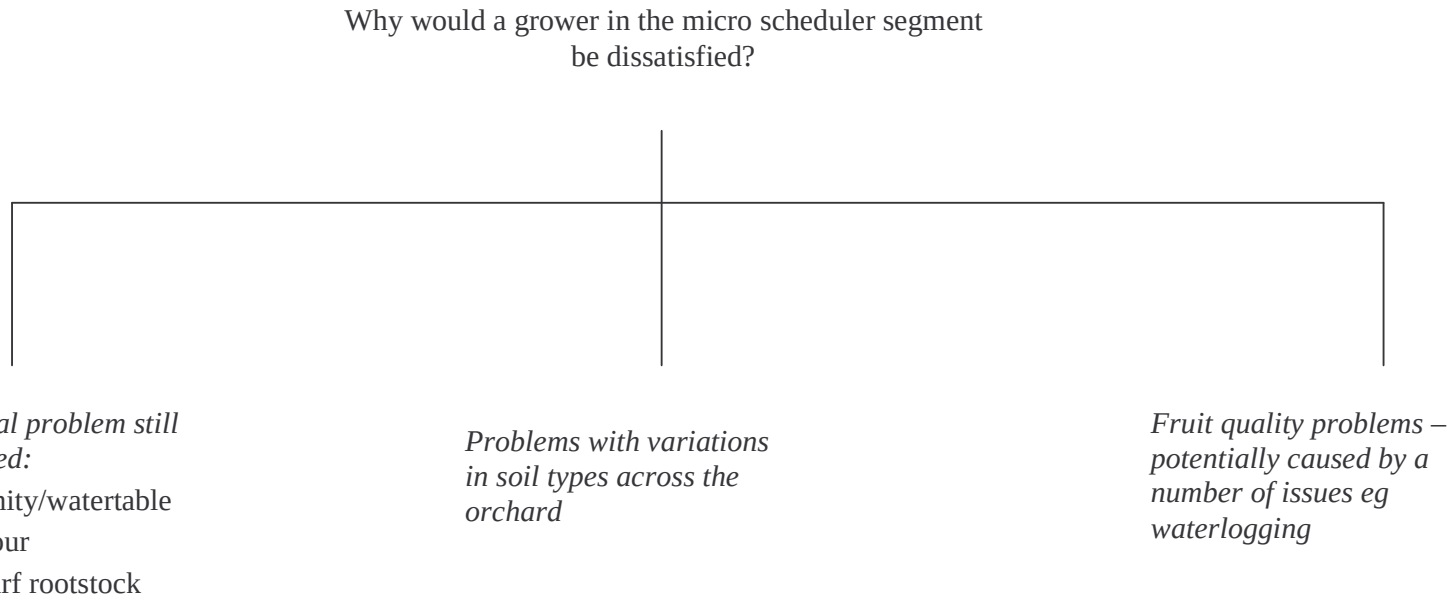
- Water availability
- Water quality



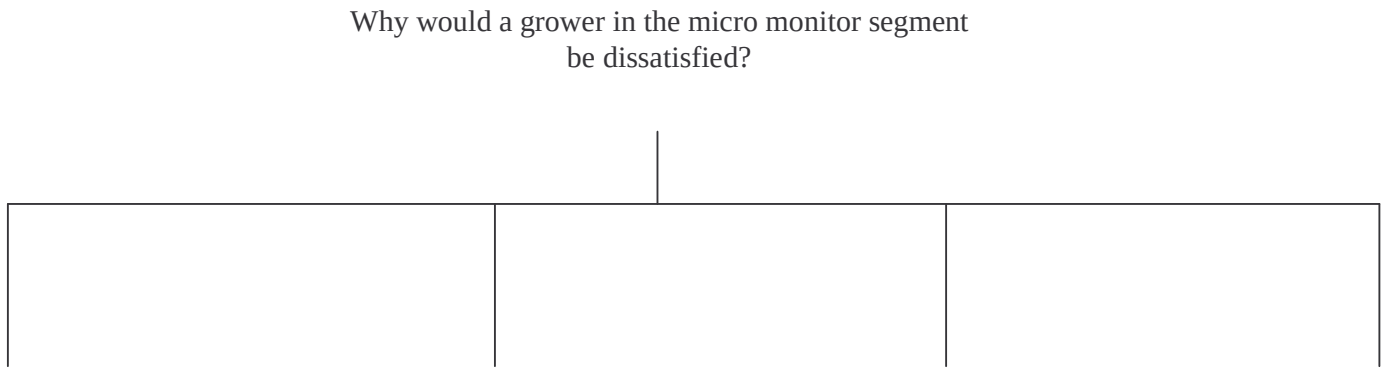
Agreed this was not an extension role – part of water authority and water policy

Appendix B

Problem tree for micro scheduler



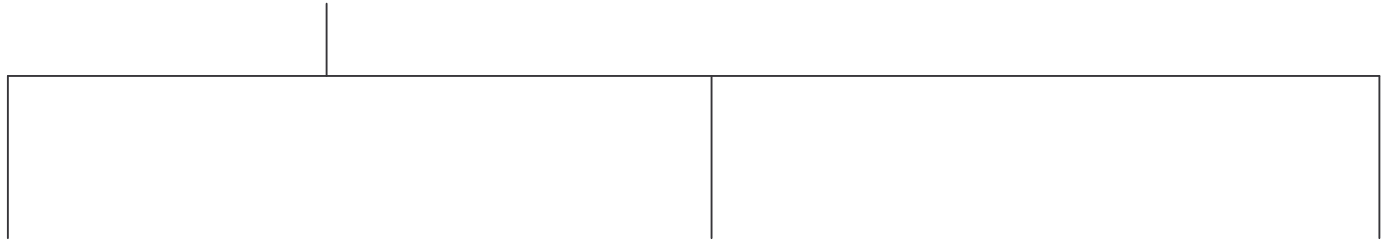
Problem tree for micro monitor



Solution trees for micro scheduler (1)

Technical problem still not satisfied:

5. Salinity
6. Watertable
7. Vigour
8. Rootstock



Provide information on:

1. Salinity
2. Watertable
3. Vigour
4. Dwarf rootstocks

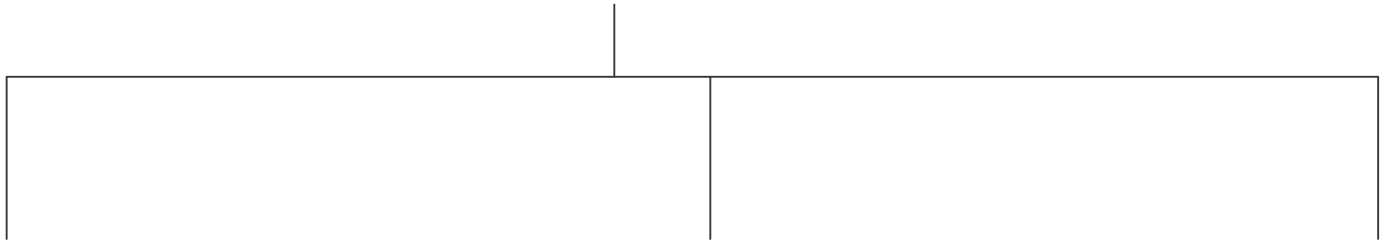
Advantage for DNRE as perceived as credible and objective information source

Assistance in dealing with problem eg. help to install monitoring equipment, undertake soil/leaf tests

Promote suitable equipment/information – that fits with grower's context. Eg if they converted to micro to save time, ensure solution doesn't increase time spent irrigating

Solution trees for micro scheduler (2)

Problems with variations in soil types across the orchard



Provide information on soil types

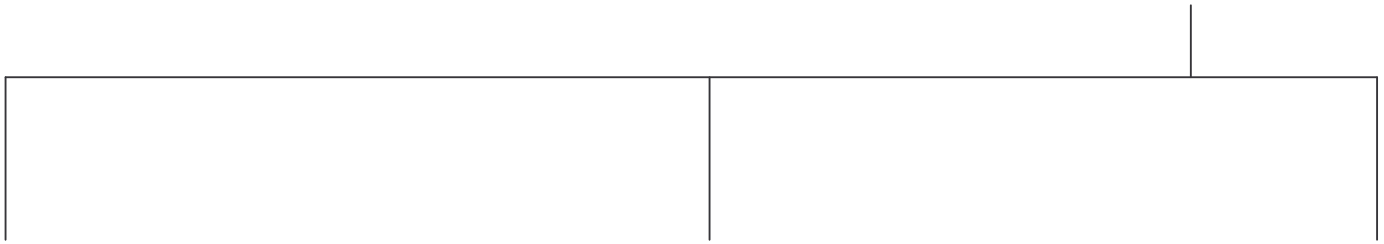
Advantage for DNRE as perceived as credible and objective information source

Assistance in dealing with problem eg. help to install monitoring equipment, undertake soil/leaf tests

Promote suitable equipment/information – that fits with grower's context. Eg if they converted to micro to save time, ensure solution doesn't increase time spent irrigating

Solution trees for micro scheduler (3)

Fruit quality problems – potentially caused by a number of issues eg waterlogging



Provide information on problem

Assistance in dealing with problem eg. help to install monitoring equipment, undertake soil/leaf tests

Advantage for DNRE as perceived as credible and objective information source

Solution tree for micro monitor

(see also solution trees for micro scheduler)