Sub-surface Drip Irrigation

A study into sub-surface drip irrigation

A report for NUFFIELD AUSTRALIA FARMING SCHOLARS

by Mathew Stott

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In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

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Foreword

It has become apparent that the current drought, or "period of dry," as now labelled by the Federal Government, is impacting upon the availability of the natural water resource that all irrigators are dependant upon. In addition, State and Federal Water Policies are being developed which impact both surface and ground water irrigators in the Murray Darling Basin. These policies have already started impacting upon the viability of irrigators in the Murrumbidgee Irrigation Area, as ground water irrigation allocations have been permanently reduced. The decision was made to base this Nuffield study on water and sub-surface drip irrigation (SDI), with the aim to assist in ensuring the survival of the irrigation industry in the region. With the support of the Grains Research and Development Corporation the role of SDI in irrigated cropping was investigated.

The Stott family farm operation began in 1977 at Whitton as a 200 hectare rice, sheep and wheat mixed enterprise, located in the Murrumbidgee Irrigation Area. This family farming business has now increased in size with the addition of neighbouring farms and two larger properties at Darlington Point. The family farm now consists of a total of 2,500 hectares. The family business has moved away from traditional cropping practices to niche market crops such as seed crops, wine grapes and processing tomatoes. Seed crops include sunflowers, corn, sorghum, onions, carrots, lucerne, canola, wheat, triticale, oats and lettuce. Also included in our cropping rotation are commercial crops such as popcorn, tomatoes, wheat, barley, faba beans and wine grapes. We also run approximately 800 ewes and 500 cattle, mainly on agistment in New South Wales.

Through this scholarship it was hoped that an answer could be obtained to the question, "Do we as a family attempt to purchase more water or can we implement new technology to improve our current on-farm water use efficiency?" Upon visiting and speaking to growers across the world the decision was made that some of the disadvantages of SDI could be overcome. Upon returning home these ideas were immediately evaluated and trialled on farm. Two different systems were trialled during the 2008/09 season; a high pressure system at Whitton consisting of 35 hectares and a low pressure system of 30 hectares at Darlington Point.

At **Whitton**, the high pressure system was extremely successful growing popcorn and seed lettuce. The standout of the high pressure system was that the tube used had pressure compensated emitters, which means they deliver the same amount of water at both ends of the system. This system was very expensive initially but 100% uniformity is achieved, and the system can be amortised over a 30-year life expectancy. The popcorn crop had a very poor plant stand, primarily due to the rain and cold weather immediately after sowing and watering up. However, a yield of 6.5 tonnes/ha was achieved which was surprisingly good taking into account the poor start to the crop. The water usage was approximately 1.5 megalitres less per hectare than conventionally irrigated popcorn crops. The seed lettuce looked fantastic all season, but until the final seed grade outs are received the final result will not be known. During late January, early February the area experience a period of 13 days with temperatures above 40°C degrees. No crop on the farm thrived in that weather!

At **Darlington Point**, the low-pressure system had mixed results. 15 hectares of seed corn and 15 hectares of processing tomatoes were planted in the block. As the season progressed it was apparent that the distribution was uneven across the field with the crop closest to the supply end of the tube receiving more water than the far end of the rows. This was due to the following factors

- There were different emitters in the high pressure (pressure compensating emitters) and low pressure (non-compensating emitters) systems, thus resulting in an uneven distribution due of the lack of pressure in the low pressure tube.
- Filters were constantly blocked due to the very fine sand. This was unforseen and became a major problem during the trial. Following installation of additional filters, we then had problems with algal growth.
- To solve the above problems, we had to resort to watering only half the block using the irrigation system (tomatoes) and watering the balance (seed corn) by syphons. This would not have been possible if we had not kept our existing syphon irrigation system in place.
- The system was designed primarily for Israeli conditions and smaller overseas operations that employ cheap labour.

The above project was conducted in conjunction with Netafim Australia and Irrigation Specialists of Leeton, New South Wales

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This study would not have been possible without the generous support by the Grains Research and Development Corporation and Nuffield Australia. I did not attend university but found this opportunity has enhanced my education and I am extremely honoured and grateful to have be selected to participate in the Nuffield experience.I would also like to thank Jim Geltch for organising a fantastic and exciting Global Focus Program. It was very informative, well planned with an excellent selection of places we visited. To my fellow 2008 scholars, thank you for making my Nuffield journey both an enjoyable and memorable experience. I look forward to maintaining our friendship and support as we continue our lives into the future.

I would also like to sincerely thank my family, my wife Hannah for being supportive and understanding of my desire to be a Nuffield Scholar and to further myself as a businessman. She organised our wedding whilst I was on the Global Focus Tour and assisted me in California & Arizona with my research. Thanks to my parents who encouraged me to keep learning and to extend myself, and I'm grateful to my brother Andrew who picked up the slack on the farm whilst I was away.

I met so many great and interesting people during my travels. They selflessly gave up and their time and for that I am extremely grateful to them. The following people deserve special mention:

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- Don May – Westside Field Station, Four Points California
- Scott Tolsen – Del Monte Foods, Arizona
- Carlos Garcia - Arizona Ranch
- Louis Churnside – Kerang, Victoria and Karhovka, Ukraine
- Dennis Moon - Rochester, Victoria
- Tony Sawers – Boort, Victoria
- Tim Watson – Hillston, New South Wales
- Amaro Partners – Griffith, New South Wales

Abbreviations

SDI = Sub-surface drip

ML = Megalitre

MIA = Murrumbidgee Irrigation Area

Executive Summary

Water is becoming an increasingly limited natural resource throughout the Murray Darling Basin. Irrigators are finding that current State and Federal Water Policies are now impacting upon their irrigation farming businesses and their continued ability to produce food and fibre for the country. The time has now gone where water is always available for purchase at an affordable price. Innovative farmers must continually investigate and evaluate new technologies to improve on farm water use efficiency to ensure their viability into the future.

This report is relevant to all innovative irrigators who are keen to implement new ideas and technology on farm. All irrigators do not need to adapt these ideas and technologies to their own farm, but can learn from the experiences of others in the region, not only saving time but also dollars required for this trial and error process which farmers often use.

To fully investigate the role of SDI the decision was made to not only visit growers in countries that have fully adapted the technology to their soil and farming system like Australia, USA, and Canada, but to also visit countries that are in the process of developing an irrigation industry, such as Brazil and the Ukraine.

SDI is known to have a number of advantages and disadvantages. SDI may not always result in on-farm water savings, although it has been demonstrated in some areas that water savings may be in the range 30-50%. But in all most cases SDI has been shown to improve the on-farm water use efficiency and distribution uniformity.

SDI has been used successfully to produce a range of crops, including high value horticultural crops such as processing tomatoes and melons, and also, more recently corn, maize and lucerne, and is suitable for use in undulating paddocks. It enables water to be applied to the growing crop, in the root zone, on a daily basis, supplying a small amount of water without creating a damp microclimate at the soil surface. SDI can also be used to supply a range of nutrients directly to the growing root hairs, as required by the plant.

Although SDI systems do have a large number of advantages, there are some disadvantages, which do prevent this technology being more widely adopted. These include the potential of mechanical damage occurring to the tape during tillage of the soil. In addition, as soils dry they often crack open leaving the tape potentially exposed in the crack. This allows rodents to enter the crack to eat the fallen grain, and also chew the tape. Insect damage may also occur to the tape as they search for water in the soil. Root intrusion of the emitter may also

occur, resulting in blockages, causing over and under watering of the block. Crop establishment using SDI may also be difficult depending upon depth of tape and soil type. One of the largest hurdles to SDI is perhaps the initial set up cost, although it was observed during this study that a SDI system does not need to be the top of the line to work efficiently.

This study attempted to fully investigate both the pros and cons, and consider options and methods, to overcome some of the known disadvantages, which appear to prevent growers readily adopting this technology.

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Introduction

Irrigators within the Murray Darling Basin have all become aware that the natural resource called water is becoming increasingly limited. All irrigators need to maximise the use of every drop, with either drought, or "period of dry", and government regulations impacting upon irrigation allocations throughout the Basin.

As a young irrigation farmer I could see the challenges that will be ahead to continue producing high-yielding crops on our current farm, but with less water available for irrigation, and potentially less stored soil moisture due to the impact of climate change and government regulation. In addition water saving technology may assist in reducing our farm labour requirement and some farm inputs, in particular fertiliser. With increasing competition now occurring globally between food and fuel production it is more important than ever that irrigation farmers aim to improve their on-farm water use efficiency, to enable them to produce more with less water. This will not only result in potentially higher gross margin returns but will also ensure that irrigated food production remains a viable option into the future.

Sub-surface drip irrigation was chosen as the topic as this method of irrigation is know to be one of the most efficient, and uniform methods of applying irrigation water, and also able to provide water to plants as they require. Other forms of irrigation such as border check or flood are often considered inefficient, resulting in a higher water requirement with plants being stressed by being subjected to conditions at varying times which can be either too wet, or too dry. Overhead irrigation using centre pivots or travelling guns can result in high evaporation levels during our summer period, or being unable to irrigate during high wind. In addition their distribution uniformity is generally between 60-80% compared to SDI, which can be as high as 93%, depending upon the installation. Overhead irrigation may create an ideal micro-environment in the crop, resulting in the establishment and spread of plant fungal diseases.

Sub-surface drip irrigation has been trialled in the Murrumbidgee Irrigation Area in the past, with tape buried at 15-25cm deep in the heavy clay soils. These trials have not been successful due to a combination of factors, including:

- Difficulty in wetting up, resulting in poor crop establishment,
- Mechanical damage during the season from farm implements.

The Nuffield Scholarship provided an opportunity to visit a number of irrigation farms across the world, to inspect and discuss irrigation practices with a number of farmers. Innovative farmers are known to adopt technology and then modify it to suit their own conditions. This often occurs through trial and error over a number of months or years. By visiting a range of farmers and hearing first hand their experiences it was hoped that some of this trial and error experimentation might not be necessary and the available technology could be adapted to our environment in a shorter and less costly time period.

With the introduction of recent government regulations impacting significantly upon farming businesses throughout the Murray Darling Basin, and especially in the MIA where the family farm is located, it was time to fully evaluate our options and consider implementing technology to increase our on-farm water use efficiency. As a result the family farm business will be at the leading edge of technology, ensuring the survival of not only our irrigation farming business, but also the local community and the irrigation industry.

World Wide Agriculture

Water is essential for the production of agricultural crops across the world. Water Policy and the use of water for agricultural production is becoming a topic of interest in many countries as the urban demand for water increases and drought impacts on a number of the key agricultural production regions. Water used for agricultural production is obtained from a variety sources with varying degrees of reliability and quality.

Brazil

Farming in Brazil in the region north of São Paulo, north of the Tropic of Capricorn (similar latitude to Darwin-Kununurra) was predominately reliant upon natural rainfall. The annual rainfall through this region was approximately 3,000 mm, with the country having access to 13% of the world's fresh water. Irrigation water was sourced from on farm dams which filled each year through natural rainfall and runoff. One farm visited had a 1,000 ML dam which filled each year, with 800 ML used annually to irrigate his processing tomato crop. No regulations were in place to restrict farm dam construction and the capture of on-farm water.

Approximately 60 million hectares of crop are produced annually in Brazil, of which only 3 million is irrigated. Agricultural production is approximately 13% of the countries GDP. The cropped area comprises of 22 million hectares of soy, 14.4 million hectares of corn, 6.7 million hectares of sugar cane, 3.8 million hectares of beans, 2.9 million hectares of rice, 1.8 million hectares of wheat and 1.1 million hectares of cotton. This results in approximately 100,000 hectares of crop in addition to rice being irrigated. Irrigation of these crops occurs predominately via centre pivot with only a small area irrigated by drip irrigation. Centre pivots were used for irrigating a range of crops from processing tomatoes through to citrus plantations.

Agricultural production in Brazil is very much orientated towards ethanol production. The first ethanol car was developed in Brazil in 1925, and in 1979 the first 100% ethanol powered car was developed. Approximately 50% of the total sugar produced in the country is used for ethanol production.

Although the majority of the crops produced throughout the region are reliant upon natural rainfall and stored soil moisture the average yield of soy through the region were 2.8 t/ha, corn/maize 3.7 t/ha and wheat 2.8 t/ha. Rice grown using irrigation in Brazil averaged 3.8 t/ha, whereas Australian rice yields have averaged around 8.7 t/ha in the past (http://www.rirdc.gov.au/programs/rice.html). The average yields of soy, corn/maize and wheat in Brazil are considered low by Australian standards. It would be predicted that with supplementary irrigation these yields could easily be increased to what would be expected in Australia if sufficient water was available to the crop, via either natural rainfall or irrigation during the growing period. There was no evidence of farmers looking at increasing the capture of on-farm water to develop irrigation systems.

California

Irrigation water is obtained from a variety of sources, including reservoirs, rivers and bores, all of varying quality. At this stage no regulation is present which restricts the quantity of water which may be extracted via pumping from a bore. In some areas the level of concern is increasing, that as farmers continue to pump ground water from bores the salt water from the sea will be drawn into the aquifer.

Surface water in California is very heavily regulated, unlike bore water. There are two types of water allocations. In some districts the water is attached to the land whereas in others farmers must purchase water temporarily depending upon the level of allocation in that particular basin. Farmers must own land to own water. The quantity of available water is determined by a number of factors, including the level of urban demand, winter rainfall and state and federal government policy. The state owns approximately 55% of the available water while the federal government owns 45%. Irrigation water is distributed via a network of channels and rivers. Farmers throughout the region felt that water supplied directly from rivers was deemed the most reliable and secure. In one region the available irrigation water was reduced to 35% in 2008 due to the presence of a small fish called a Delta Smelt spawning in the vicinity of the large pumping station in the delta. The U.S. Fish and Wildlife Service listed the Delta Smelt as a threatened species in March 1993 and by the California Fish and Game Commission in December 1993. Delta Smelt are considered environmentally sensitive because they only live one year, have a limited diet, and reside primarily in the interface between salt and freshwater. Farmers though the region also mentioned that this Delta Smelt was not a native of the delta but regulations had been put in place to protect it at the expense of their irrigation water. It appeared that farmers through the irrigation district in California were experiencing both a natural drought and a "man-made" irrigation drought.

Approximately 4,450,000 million hectares of ground is irrigated in California. This is used to produce a range of crops including processing tomatoes, cotton, perennial tree crops, lucerne and cereals. Sub surface drip irrigation (SDI) is used to produce approximately 40% of the processing tomatoes in California. In the Westside area up to 45% of the total irrigated area is irrigated via SDI. Typically the drip tape is buried between 35-45 cm deep, although one farmer made the comment that they though the tape could be buried between 50-62 cm deep as the water table is rather high. GPS is used to form both the beds and lay the drip tape. This enables the farmer to come back to the SDI block and reform beds knowing that the drip tape will remain in the centre of the bed.

SDI is widely used by some growers with two farms visited having developed between 5,600 to 8,000 hectares. These farms grew a diverse range of crops including both annual and perennial crops. This enabled the farmer to spread their risk and not be reliant upon one particular crop, processing company or market. In turn, as the availability of irrigation water becomes limited growers determine where the water should be used. Perennial crops, including organic walnuts, almonds, wine grapes and pistachios are allocated water first. The remaining water is then allocated to the annual cropping program, with those crops offering the highest return being produced. As a result the area of cotton produced in California has decreased in the past year due to low cotton prices and limited irrigation water. As a result of this competition for irrigation water the price of processing tomatoes has increased.

Temporary irrigation water may be purchased for between $90 to $200 /ML, depending upon the region. Water availability and price through California is now impacting upon agricultural production, with some growers considering innovative options to enable them to produce more with less water.

John Diener's farm operation, Red Rock Ranch, near Five Points California, is affected by saline soils and shallow water table. In 1995 he had 12 hectares which became salted out. He has been working with researchers since 1996 to utilize integrated on-farm drainage management, a system that captures and reuses irrigation water.

He draws water from approximately 480 metres to use for irrigation. This water is located between confined layers and is pressurised. The Westside region consists of over 202,000 hectares of farming land. Their annual rainfall is approximately 150 mm. The Westside area has a perched water table. This has resulted in considerable salinity issues on his farm. Eucalyptus trees are been planted around the far side of the farm to help channel and use the water which runs off the hills. Ground water monitoring occurs with the use of pziometers.

For some years the groundwater pumping became limited, which impacted upon his on-farm agricultural production. This resulted in him considering and implementing options to ensure he was able to maximise the irrigation efficiency of his available water. He implemented a tile drainage system which took 4-5 years to become fully operational. He has used drip irrigation in the past but has not been happy. He irrigates his lucerne using a centre pivot. He also has a pistachio trial to determine the maximum level of salt they can tolerate. In the long term he would like to use a maximum of 0.8 ha to solve his salinity problem instead of the current 260 hectares. The water is continually re-used on the farm and is often blended with fresh water. Other crops grown by John include safflower, carrots, triticale, almonds, lucerne, grapes, walnuts and tomatoes.

John is looking at methods to improve his water use efficiency and to utilise every megalitre of available water. He is currently trialling a solar evaporation area where salts are captured from the water after its final use so that no salt or selenium is discharged back into the environment. The water at the point of entering the solar evaporation area has been re-used a number of times (3-4) and has a salt content similar to sea water.

The process consists of a steam generator which is adaptable to solar or wind power. 20 watts is required to generate 1 gallon of distilled water (90% clean and 10% salt). 16 watts is used to generate 1 gallon of distilled water at 70% clean and 30% salt. The cost of energy is critical at this stage as the outputs from each stage need to be of sufficient value to compensate for the cost of the process, including energy.

Permanent water currently costs between $400-$500 /ML. In town the cost of water is $1000 /ML. Approximately 250 ML of water can be obtained as drainage water off a paddock. This quantity of water will grow approximately 25 ha of almond trees.

The water goes through a series of treatment processes, with the products at each stage being worth enough to cover the cost of all inputs. For example, he has a tank set up with a paddle which breeds brine shrimp. These shrimp take the selenium out of the water; they are then dried and sold to the dairy industry as a source of selenium. Approximately 40kg of shrimp can be obtained from 1 m^3 of water. Boron is another element which is extracted from the water. No salt or selenium is discharged back into the environment.

In Arizona the water is obtained from the Colorado River and bores. The cost of water from the river is approximately $50/ML. It has been observed in the area that as farmers have converted from flood to drip irrigation the quantity of water extracted from the ground has decreased from approximately 9m to less than 30 cm per year.

Canada

Agricultural production in Ontario, Canada has previously been reliant upon natural rainfall and stored soil moisture for the production of a range of crops, including processing tomatoes and corn. More recently spring and summer rainfall has become a little less frequent and growers are now considering irrigation to ensure they are able to maximise crop yields.

Ukraine

The Ukraine appeared to have an abundant supply of irrigation water with no or very little regulation. Agricultural production is reliant upon natural rainfall and stored soil moisture, with dry land crop yields of around 5 t/ha for barley and 8 t/ha for wheat. Sub surface drip irrigation is currently being developed for tomatoes and onions, with ground water being used which is located less than 3m from the surface.

Australia/Murray Darling Basin

The Murray Darling Basin is currently experiencing a severe drought and subsequent low irrigation allocations. The Stott family farm is located in NSW at Darlington Point; in the Murray Darling Basin. It has become apparent to all irrigators located within the Basin that both surface and ground water is a limited resource and that all users need to maximise on-farm water use efficiency. The resource is becoming increasingly regulated with irrigation allocations being both temporarily and permanently reduced. The price of both temporary and permanent water at the same time is increasing in value due to the impact of supply and demand.

The Federal Government during the past year has implemented a number of programs in an attempt to improve on-farm water use efficiency with varying success. Innovative farmers located throughout the Basin are currently being proactive in an attempt to improve their on-farm water use efficiency, and produce more using less water.

Sub-surface Drip Irrigation

Sub surface drip irrigation or SDI has been adopted to varying degrees across the world. During this study a number of farms were visited throughout California and Arizona in the USA, Ontario in Canada and the Ukraine, in addition to speaking to farmers in Australia. In each place the technology had been adapted for the local conditions and had been used on-farm for varying lengths of time.

SDI Globally

In California a number of farms were visited who had established SDI systems, with a number of these systems having been established to irrigate processing tomatoes. The initial uptake of SDI through many parts of California was slow, with some of the understanding that using SDI may actually decrease their soluble solids levels in their processing tomato crop. This thinking came about as processing tomato crops may produce higher yields using SDI but some processing tomato varieties do display an inverse relationship between yields and soluble solids, thus a higher yield, the lower the soluble solids. This does not appear to be as much of an issue now for growers as some of the new varieties grown using SDI do not exhibit as strong a relationship between yield and soluble solids. In addition as water has become more limited growers have adopted technology to increase their on-farm water use efficiency.

A number of farms throughout California have established significant areas of SDI; the tape is all laid using GPS and the beds formed with the tape positioned in the centre of the bed. The beds are then retained and GPS used for all tillage operations. Water is delivered across the farm in many cases using a 35 to 45 cm pipe.

Stamoules Produce had developed over 5,500 ha of SDI in a 10 year period. This had required considerable capital investment, requiring 22 filter stations and 279 valves. They produced broccoli, sweet corn, melons and peppers. The SDI was laid as 2 rows, 71 cm apart in a bed a little over 2 m in width. The emitters were at 30 cm spacing with a flow rate of 0.16 cm/hour. The tape in this particular case was buried 30 cm deep. This system was capable of producing 3 rows of corn per bed, and enabled them to double crop approximately 800 ha of sweet corn.

Chabello at Bakersfield used SDI buried at a depth of 35 cm, as one row per bed, approximately 1.9 m apart. They used a low pressure system of 13mm width. The cost of the equipment for this system was approximately $1000 US/ha with them undertaking the installation. With the adoption of SDI they have decreased their water usage on cotton from 3 ML/ha to 1.3 ML/ha, while at the same time experiencing a slight increase in yield. Irrigation water in this case was obtained from 15 bores.

Chuck Dees had also installed a significant area of SDI. His system was installed 30 cm deep, as 2 rows in approximately 2 m beds. Each row was positioned 35 cm from the centre of the bed. From his experience he had found that the 15 and 10 mm tape could last up to 10 years in the ground. He used two different emitter spacing's, some at 45 cm with the majority at 30 cm. He pre-irrigates all the ground to ensure good crop establishment. His estimate of the cost of the SDI system is $3,000 to $3,700/ha, fully installed, with everything buried and individual flushing for each tape.

In many cases SDI was not used by growers in California for crop establishment, due to the difficulty in wetting up from 30 cm deep. Growers would use some form of overhead irrigation or flood irrigation during the establishment phase before swapping to SDI later in the crop life. Growers in California were able to use a combination of two irrigation systems as the overhead system or flood irrigation used for crop establishment was often low cost but high labour. The cost of labour in California, although increasing, is still a more affordable option for growers than investing in additional high cost infrastructure.

Arizona is another state which has farmers who use SDI. Scott Tolsen put his first installation in the ground in 1980. This tape is still in the ground and working well, he does not pull the tape up each year. He uses drip irrigation to produce two crops per year, rotating between rockmelons and cotton. Unlike many farmers in California he does not use a second irrigation system to wet up as he is 100% reliant upon his drip irrigation system. The permanent SDI installations consist of a sub-mains buried 75 cm deep in a narrow trench. Beds are then formed on his blocks before the drip tape is installed. This is to ensure the tape is placed in the centre of the beds, although he now finds using GPS which enables the tape to be laid more accurately in the centre of the bed, thus potentially prolonging the life of the tape. He uses two different emitter spacing's on the farm. For melons the emitters are approximately 2 m apart, whereas for all other crops they are spaced at 1 m intervals. The tape is buried 30-35 cm deep. He uses Netafim Typhoon tape of 10 mm diameter with turbulent flow emitters. The tape is flushed 3 times per year.

Using SDI, Scott has reduced his water usage from 5-6 ML/ha on cotton to approximately 3 ML/ha. In melons he now uses as little as 1 ML/ha. With the increase in return for lucerne he is now using drip tape with 1 m emitter spacing for lucerne production. His soils are loamy to sandy, with the loam soil having a water holding capacity of around 4.5 cm/30 cm and his sandy soil around 2.5 cm/30cm.

Farmers through California and Arizona have developed techniques to till their soil above and around SDI systems. In Arizona the Sundance toolbar was developed. This enables the soil to be deep ripped between the drip irrigation rows. This is similar to a toolbar developed in California by Alan Wilcox, called a Wilcox Eliminator, specially built for intensive row crop farming systems. The concept of the machine was to break down the trash or stubble from tomatoes, corn or wheat with one pass, without disturbing the SDI system, leaving a seed bed ready for hilling into beds. The machine consisted of coulters at the front followed by ripper tynes and a gang of discs in front of a rotating blade to finely chop the trash. This combination was then repeated on the back half of the machine with a flexi coil style roller at the back. The Wilcox machine is also very similar to machines commonly used in Europe where stubble retention is critical to their successful cropping.

Wilcox Toolbar

Drip irrigation in Brazil and the Ukraine is considered new technology which has not been widely adopted. Both of these countries currently have a plentiful supply of irrigation water and have not had to consider SDI for improving their water use efficiency. SDI is currently being used in both countries for some of the higher value crops like processing tomatoes and onions. Farmers in the Brazil and the Ukraine do not have access to sufficient levels of capital to enable adoption of new higher value technology. With cheap labour, at around $15/person/day, farmers are often required to look at cheaper "home made" alternatives to the high cost technology. When visiting the Ukraine a farmer using SDI had built his own cheaper version of a filter. This filter appeared to be working well and demonstrated that SDI systems to not have to be the top of the range and expensive to implement.

"Home made" SDI filters in the Ukraine

SDI Australia

SDI has been used in Australia for a number of years, with growers having adapted systems to suit their soil type and environmental conditions. The processing tomato industry located in Northern Victoria and Southern NSW began using SDI in the early 1980's, but adoption was slow due to poor technical support and crop quality problems. In the mid 1990's SDI become adopted at a higher rate, with approximately 15% of the total area used to produce the Australian processing tomato containing SDI. This increased to approximately 50% of the total area by the end of 2000. Adoption occurred rapidly during this time as growers were able to obtain significantly higher crop yields. At that time irrigation water was not a limiting factor. More recently, during the current drought, growers who had not used SDI in the past are now also installing systems to ensure that their on-farm water use efficiency is improved and that they can grow more with less water.

SDI being installed for a processing tomato crop

SDI is also used for a number of other crops in Australia in addition to processing tomatoes. This includes melons, fresh tomatoes, lucerne, corn, maize, cotton and wheat. Initially adoption of SDI was slow, but as both surface and ground water have become more limited and regulated growers are now expanding their SDI area and using it to produce a wider range of crops.

During the 2004-05 season Sawers Farms, at Boort in Victoria used SDI to irrigate maize in an attempt to increase production and lower costs. They grew 232 ha of maize on beds, with beds spaced at 1.63 m, with one single drip tape per bed. The tape was buried approximately 25 cm deep with emitters spaced at every 50 cm. This SDI system cost approximately $3,750/ha to install and had been in the ground for 6 years, having been used previously to grow processing tomatoes. The maize was grown in two rows on either side of the tape, and had been irrigated solely by drip irrigation. Total average crop water use was 6.67 ML/ha across the whole area. To ensure adequate soil moisture for germination of the seed the SDI system was run long enough for the water to totally "black" out the bed, and almost be running out the sides. This then provided a reservoir of soil moisture for later use, with the SDI system being operated in the future on an as needs basis. Water did not come to the bed surface again at any stage of the crop life. At harvest the maize yield averaged 19.2 t/ha of grain, compared to 12-15 t/ha from furrow irrigated crops on other farms in the region. In addition the amount of water used was reduced by 20%.

Processing tomatoes are also grown on drip irrigation systems on beds ranging in width from 1.5 to 1.63 m in width. In all crops in Northern Victoria the tomatoes are planted in one row along the centre, of the bed directly above the buried drip tape. The tape during the mid 1990's was buried at around 20-30 cm deep and intended to remain in the ground for 3-4 years. As growers became more accustomed to the technology they began laying the tape deeper with the intention that the tape would remain in the ground for more years. Some growers during this time have also invested in specialised machinery from the USA to assist with the tillage of the soil above and around the SDI system.

SDI has also been used by central Queensland irrigators on lucerne since the early 1990's. This occurred as a result of diminishing ground water and the need for growers to improve their on-farm water use efficiency. These growers have successfully used SDI to produce a range of other crops including maize, mungbeans, sorghum and wheat. They have also found that the water use savings, when using SDI, ranged from 0-50% when compared to traditional irrigation systems. In situations when water savings were not experienced the overall water use efficiency did increase due to the increase in crop yield. Growers through this area have found that it can be difficult to establish crops using SDI. This is very dependant upon the SDI system and soil type, but if farmers have access to either overhead or flood irrigation they have opted to use these to ensure good germination and crop establishment. Growers who do not use overhead or flood irrigation for crop establishment have often been required to pre-irrigate to fill the soil moisture profile.

A number of Australian growers have now been using SDI for over 15 years, with the irrigation system not only being used to supply irrigation water to the crop on an as needs basis, but also being used to supply a range of fertilisers, including nitrogen to the plant to match their growth requirement. This has resulted in an increase in savings, by not only reducing the quantity of water used, but by also decreasing the total quantity of fertiliser applied to the crop.

Advantages

SDI has been used across the world to produce a range of crops. Although initially used for higher value horticultural crops it is now also used for lucerne and wheat, resulting from the need to increase on-farm water use efficiency and produce more from less water.

SDI may not always result in growers being able to use less water for a given planted area, but will almost always result in increased crop yields, thus improving the overall water use efficiency.

SDI has greater distribution uniformity, (generally greater than 85%) than other forms of irrigation, and water application is not affected by wind or evaporation. SDI is not as greatly affected by variable soils, providing the crop establishment is uniform. SDI is also suitable for use in undulating paddocks which could not be irrigated by flood irrigation, thus has potential to increase the farm area which can be used for the production of irrigated crops.

SDI enables water to be applied to the growing crop, in the root zone, on a daily basis, supplying a small amount of water to the plant to replace what the plant may lose to evapotranspiration each day. As small amounts of water can be applied to the crop on a daily basis the crop is never stressed from being too wet or too dry, as in the case of flood irrigation. This also enables access to the paddock at any time to ensure the application of pesticides occurs in a timely manner, along with the ability to irrigate the crop up until the point of harvest, if necessary. SDI, unlike other irrigation systems does not result in the creation of a damp microclimate at the soil surface. This is beneficial as the damp microclimate may be ideal for the establishment of some plant pathogens.

Overall crop agronomy also benefits from the use of SDI as the irrigation system can be used to apply not only water on an as needs basis, but to also supply a range of nutrients directly to the growing root hairs. In some cases systemic insecticides can also be applied via SDI.

Once installed the labour required to operate a fully functional SDI system is significantly lower than that required for many overhead and flood irrigation systems. SDI systems may be fully automated and operated electronically using a computer based in the home office. More recently these systems are now operated via notebook computers and mobile phones, enabling growers to continually monitor and control their irrigation from any location. SDI has enabled one person to irrigate a far larger area than what previously could have occurred using flood irrigation.

Disadvantages

Although SDI systems do have a large number of advantages, there are some disadvantages which do prevent this technology being more widely adopted. These include the potential of mechanical damage occurring to the tape during tillage of the soil. Growers in Australia already using this technology have also found that the tape is damaged by insect and rodents. This is especially evident when the SDI is used to irrigate cereal crops on heavy cracking clay soils. As the cereal crop approaches harvest and the soil profile dries out, the clay cracks open leaving the tape potentially exposed in the crack. This allows rodents to enter the crack to eat the fallen grain, and also chew the tape. Insect damage may also occur to the tape as they search for water in the soil.

If the SDI system is not carefully managed root intrusion of the emitter may occur, resulting in blockages, causing over and under watering of the block. This was observed in the Ukraine where growers were not accustomed to the technology. If the SDI system is operated too dry plant roots will grow in search of water and enter the emitter. This can be prevented in some cases by running a very small quantity of pre-emergent herbicide through the tape, and by ensuring the soil around the tape never becomes too dry.

Crop establishment using SDI may also be difficult depending upon depth of tape and soil type. In some situations growers have been required to use either overhead or flood irrigation for crop establishment. This can be costly as growers must invest in two distinct irrigation systems.

The movement of salt and nutrients in soil irrigated via SDI is a topic that has not been widely studied. A number of growers and agronomists have observed what appears to be the accumulation of salt on the edge of the wetted zone or soil surface. It is also thought that nutrients required by the plant may be leached from the root zone due to the constant wetting of the area. This may become critical in the future as SDI systems become more permanent.

One of the largest hurdles to SDI is perhaps the initial set up cost. Typical SDI systems consist of expensive sand or disc filters (or in some cases in Brazil both were used together), pumps, fertiliser and chemical injectors, water meters, pressure gauges, field valves with pressure regulators, sub-mains and drip lines. In some cases a farmer may look at the initial establishment cost and just say it is not worth it for what they might consider the small water savings to be. During this Nuffield study it was observed that a SDI system does not need to be the top of the line to work efficiently. Innovative farmers in the Ukraine were able to manufacture cheaper alternatives on-farm.

Typical SDI systems across the world also require significant energy to operate the pump. This is often in the form of diesel or electricity. Electricity as a power source is very limited and not widely used as many growers do not have access to power where pumps are located on-farm. As a result traditional SDI is very reliant upon diesel, which is not only expensive, but also results in the emission of greenhouse gas.

Although some people may look at these disadvantages and say that SDI is just not worth considering, growers need to look outside the square and consider alternative systems which may overcome some of these. A low pressure system or the use of home made components may assist in overcoming the increased cost of establishment and operation.

Comparison of Systems

When implementing new technology into a farming system it is important to compare the pros and cons of both the existing and new technology.

The current method of irrigation used on the family farm consists of Beds-in-bays, Channel Check. To maximise water distribution uniformity ground must be firstly laser levelled. This can be a high cost practice ($1,600-$2,000 per hectare), which can result in considerable movement of soil. In addition pipes and headwalls, which are also expensive structures, are installed, with the cost estimated to be approximately $25,000 for 100 ha. This system also has high ongoing maintenance costs, e.g. excavator costs, and a high labour requirement. A higher volume of water is required to gain efficiency of the system, with yet unproven water savings occurring. This system is suited to selected crops such as rice, cotton and maize, but is not suitable for the production of some seed crops. Drip irrigation on the other hand is not suitable for the production of all crops, for example the currently available rice varieties can not be produced using SDI. Netafim did conduct some trials in Australia a few years ago in using SDI to grow rice but were not successful. Rice varieties currently grown in Australia do not appear suited to drip irrigation.

SDI systems may be Low or High pressure systems. A Low Pressure System is marketed as being suited to an existing bore and lower cost. The water is raised to a specific level to create sufficient pressure to operate the system. Tape was laid on the family farm during the 2008/09 season using 1.8 m bed centres, with emitters at 0.5 m spacing's. The system can be established at a low cost, with one in-line filter and lay flat as the sub-mains, with manual operation. This system, depending upon the tape used can be a more temporary option, estimated to last between 3-5 years. This system has been shown to produce irrigation uniformity in the range of 80-85%. The original cost of installing this type of system was estimated to be in the range of $2,200-$2,600 per hectare, but after the difficulty experienced with the system on the family farm during the 2008/09 season, and the cost of PVC sub-mains, the estimated cost was in the vicinity of $5,000 per hectare.

Installing SDI during the 2008/09 season

A High Pressure system on the other hand is considered a higher cost system. This system may be totally buried below ground level, with all mains, sub-mains and drip tape buried. The High Pressure system trialled on-farm during the 2008/09 season was also laid at 1.8 m spacing with 0.5 m emitter spacing's. Harder tube, not tape was used, with pressure compensating emitters. The filters were automatic flushing and required less labour than the low pressure system to operate. The cost of installing this system in the field was estimated to be approximately $6,200 per hectare and the additional cost of the headwork's (i.e. filtration system) equated to an additional $1,200 per hectare. High Pressure systems have been shown to produce irrigation uniformity above 93%.

On Farm Learning's since Returning Home

Upon returning home the decision was made to trial SDI on the family property during the 2008/09 season. Following discussions with the local irrigation equipment supplier and Netafim Australia the decision was made to trial both a low and high pressure system. The low pressure system was to be used to irrigate pop corn and tomatoes. The high pressure system was used to irrigate a seed lettuce crop.

Lettuce Crop Irrigated Using High Pressure SDI

The Low Pressure System caused significant problems throughout the season. Irrigation uniformity was poor, with one end of the row being over irrigated whilst the other was under irrigated. The filter system became continually blocked by the fine sand, and algal growth occurred on the filter. Following the first season's trial the decision was made to change the pump and filters on the low pressure system, to turn it into a pressurised system. A High Pressure System which was trialled in another block proved far more suitable for our farming operation, mainly due to the higher level of automation and ease of management, and also due to the increase in distribution uniformity of the water.

SDI also created a range of unique issues. Upon trialling SDI on our farm we developed our own solutions to overcome some of the known disadvantages of the system as follows:

- With SDI it is difficult to establish a plant stand on heavy clay soils. To counteract this, we used flood irrigation for the initial watering.
- To minimise root intrusion, water was applied for longer periods to create a larger wetting pattern around the drip tape emitter.
- By installing the tape to depths of 30 centimetres, it was hoped that less mechanical damage would occur when cultivating soil by machinery. We may find that we will need to go deeper in our next trial.
- Animal damage was also minimised by installing the tape at the depth as detailed above. Foxes, hares and emus looking for water are the main culprits. Some insects such as crickets and ants can also an issue.

The 2008/09 season trials also indicated that we need to have smaller valve areas to increase the flexibility when growing smaller areas of specialised crops. Instead of the 15 hectare valve sections, our next installation will be in 5 hectare valves to enable this increased flexibility when growing vegetable crops and small seed crops. In 5 ha valves the SDI system will be able to be used for the smaller specialised crops and the larger grain cropping areas.

We believe that most grain crops can be grown using SDI. As mentioned, we have trialled popcorn, tomatoes, seed corn and seed lettuce during the 2008/09 season. We will continue to explore different options in the coming seasons with crops such as sunflowers, sorghum and pumpkins.

In addition to the SDI trialled on the family farm one of our neighbours after speaking to us decided to install a SDI system for lucerne production. This installation consisted of a drip tube being placed at a depth of 60 cm. This proved very successful, especially during the period of extreme heat during late January, early February whereby the crop was able to be irrigated with small quantities of water on a regular basis. The lucerne yield in the SDI block was double that of the flood irrigated crop. The neighbour was happy with the performance of the SDI block which not only resulted in a higher yield, but also required less labour and time and increased ease of management. The only factor limiting a larger area of the neighbour's property being developed with SDI for lucerne production is the initial cost of establishment of the SDI.

Summary

Australian farmers must increase their on-farm water use efficiency to improve their farm productivity. SDI can be adapted to many different types of farming systems and has been shown across the world to improve water use efficiency, in some cases by reducing the amount of water required to produce a crop, while in others resulting in an increase in crop yields.

It is forecast that globally there will be issues of food shortages. SDI should be considered an important technology in helping overcome this issue, by enabling farmers to not only produce more food per mega litre of water, but also produce more food per hectare of available ground. Currently where SDI has been used across the world it has been found that this is in fact possible, and has been achieved in various crops to date.

Farmers throughout Australia must consider options to improve their on-farm water use efficiency. In the past farmers have had access to almost unlimited quantities of water for irrigation, this is likely to never occur again due to both the change in current climate and also due to water being given a real value. The availability of irrigation water in the past is likely to never be experienced again. Drip irrigation is suitable for many farming systems that have access to reliable sources of water, i.e. water which is available on-farm throughout the season.

My studies indicate that you will use similar amounts of water whether you try to germinate a crop using drip, or you use a furrow irrigation system. However, furrow irrigation will result in a quicker, and more even plant stand on clay type soils with very little extra cost of infrastructure. In other soil types, it is possible to germinate a crop that is directly above the drip tube, but is very dependent up the depth of the tube.

SDI should be used as a finishing tool. The crop receives moisture as required and nutrients can be delivered directly to the root zone. The crop is not subjected to the frequent drying and overwatering cycle as with furrow irrigation. Over the maturity of the crop, the grower is able to reduce the amount of water applied until physical maturity of the grain.

The learning's from this Nuffield Scholarship were trialled on the family farm during the 2008/09 season. These trials proved that SDI is readily adaptable to clay soil types in our region. Our aim was to use less water, whilst maintaining yield. However, we have found that we are only using slightly less water with SDI, but an increase in crop yield was

achieved. We will need to replicate these paddock trials over the next few years to ascertain reliable results in our farming system.

Plain English Compendium Summary

Project Title: **A study into sub-surface drip irrigation**

Nuffield Australia
Project No.:0808

Scholar:	Mathew Stott
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Objectives

To investigate the use of sub-surface drip irrigation on heavy clay soils, focusing particularly in grain crop situations.

Background

The last 15 years has seen a decline in annual rainfall combined with groundwater allocation cutbacks and government buybacks. Therefore it is imperative to improve water use efficiency. I thought that the most beneficial way to do this would be to look at sub-surface drip irrigation. The key components of the study included tape depth, tape and emitter spacing on differing soil types and tape lifespan.

Research

Travel for my topic commenced in February 2008. I studied for five months and travelled to overseas countries such as USA, Canada, Mexico, Brazil, UK, and the Ukraine. I also travelled throughout eastern Australia mainly in Victoria and New South Wales.

Outcomes

In order to improve water use you can either decrease the area planted or continue to crop the same amount of area but look for ways to reduce losses i.e. evaporation, runoff etc. To be a viable business in today's environment we still need to plant the same amount of area as we have in previous years or even increase it. Therefore, farming practices need to evolve in order to survive and prosper.

Implications

Basically, increased water use efficiency means higher gross margin returns. Sub-surface drip irrigation is the best way to achieve this efficiency. The upfront cost of setting it up is considerable but the long term benefit outweighs this as long as the system is well maintained and suitable to your needs.