Irrigation on Non-Vertosol Soils

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Executive Summary

Syphon irrigation, especially for summer crops grown on furrow irrigation in red soils, has typically been a challenge for primary producers resulting in poor yields, poor water use efficiency (WUE) and increased labour.

Red soil has a reputation for being more difficult to grow cotton and irrigate than cracking clay soil, particularly during crop establishment. Further known problems that are faced with these soil types are slow water entry at the surface, hard setting in nature and crusting and/or flaking when the soil is dry. However, with the right irrigation system design and correct management of the soil, these challenges can be overcome resulting in increased crop performance and profitability.

Both Bank-less channel irrigation (BCI) and centre pivot irrigation (CP) are two options irrigators have available to deal with the challenges faced when irrigating non vertosol soil types. These systems have advantages and disadvantages that have been explored throughout this report. The cost to implement these systems has also been highlighted and specific examples outlined. Alternative management options such as retained stubble in irrigation is also allowing irrigators to overcome the challenges of red soil on existing flood irrigation systems, negating the desire to change or implanted BCI or CP irrigation.

A professional consultant should be engaged when converting an irrigation system, and that the system is matched to the type of soil being irrigated.

Keywords

Bank-less channel irrigation (BCI), centre pivot (CP), soil texture, soil structure, infiltration rate, polypipe

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Foreword

The irrigation industry is full of great people, innovation, and knowledge. Through this research I have met and seen firsthand some amazing systems and businesses that are pushing the boundaries of irrigation. Post COVID19 has seen an irrigation industry that has faced an increase in cost of development, increased value of asset and implementation of water policy. All these factors have led irrigators to think more deeply about future irrigation investment. Getting the best return from investment was ultimately what I have explored on my Nuffield Scholarship.

In 2018, when the drought entered its second year on the east coast of Australia, and many were unaware of what 2019 was to produce, our business started to increase the analysis of our irrigation asset. At the time, there was a lack of return being generated from that asset with limited water allocation. We engaged external professionals to help identify key areas that could be improved. Even though the irrigation asset was providing a sub optimal return at the time due to drought, it was clear that when irrigation water was available it was the key driver to profitability. However, it is not easy to move your business to an irrigation focus.

The cyclical nature of the Macquarie River and more generally the Murray Darling Basin, means primary production businesses can face years where they will receive minimal allocation on their water licenses. This made us reflect on whether it was still a sound investment and whether further investment into irrigation infrastructure and irrigation licenses was ultimately worth it.

It also became a time of reflection, as we faced the reality that water availability will be a moving target into the future as the impacts of climate change increase. We also reflected within our irrigation asset on what was underperforming and it became clear that we had areas of irrigation that were performing poorly and significantly reducing our return on asset managed. This needed addressing, especially how our irrigation method was incorrectly matched to soil type.

Back in 2015-16, a poor performing summer crop on a field that had us watering every four or five days during the peak period was the final straw and we knew we had to change.

We engaged a soil scientist to understand areas where we were underperforming and with our own research, and help of others, we implemented new irrigation systems that we believe are better suited to match our soil type. During this process it was apparent that there are many irrigation system options available, the cost of systems vary significantly and the choice is vital at the start of the development phase.

Since my Nuffield journey travelling the world and gaining insight into some incredible businesses, we have:

- Developed existing irrigation furrow fields to BCI.
- Converted previous dryland country to irrigation land.
- Installed new centre pivots and made overall irrigation system efficiency improvements.
- Introduced stubble or cover cropping into traditional syphon fields to increase infiltration rates throughout the season

We have seen a significant increase in yields on particular fields which gave us confidence for further development. We have seen one field that was a surface furrow irrigated via syphons to a BCI system, and with improved irrigation management our yield has doubled and our WUE increased significantly.

We have learned the importance of understanding soil type, texture, and infiltration rate and how that impacts on irrigation. I have a strong passion for irrigation and the business wealth generated from irrigation. I hope to share my journey and discoveries to a wider industry through my learnings. Table 1 below highlights my Nuffield journey, made all the better by the people I have travelled with and the businesses that opened up to help me gain a better understanding of this topic.

Table 1. Travel itinerary

Location	Dates/duration	Visit	Brief Description
Griffith, New South Wales (NSW)	19-22 October 2019	Almonds, oranges, murray cod commins agriculture	Exploring use of ground water
Euberta, NSW	22-23 November 2019	Murray cod fish breeding	Ground water use
Tangalooma, Queensland	13-19 March 2020	Contemporary Scholars Conference	Compulsory CSC
Coonamble, Wilcannia, Bateman bay, Bemboka, NSW	Various dates in 2020	Visited four different locations exploring different businesses	An excellent program analysing each business
Singapore, France, UK, Canada, USA	5 June-12 July 2022	Nuffield Global Focus Program	A fantastic insight to agriculture across the globe
Kununurra, Katherine	24-31 July 2022	Northern Territory – LDC tour	Cotton and other crops grown in Northern Australia
Gold Coast, Queensland	16-19 August 2022	Australian Cotton Industry Conference	Direct access to growers and researchers regarding irrigation
Memphis, Arkansas, Colorado, Kansas, Texas, USA	10-24 July 2022	Visits to five US states studying irrigation	Cotton production, cover cropping, irrigation

Acknowledgments

This report and my learnings would not be possible without the support of my investor the Australian Government and Murray Darling Basin Authority (MDBA). It is wonderful to see an organisation support people within the industry that are willing to learn and share their experiences. I can only hope that my report will help the industry going forward.

Being away from the business and family was challenging. However, without the continued support of my family and the team at home, the opportunity would have not been possible, so a big thank you to them.

Also, special thankyou to our agronomist – Campbell Mulldoon.

Louis Dreyfus Company, also must get a mention as they took the time and made it possible for me to gather contacts for the research in Kununurra, Katherine, and the United States, I am forever grateful for the opportunities they provided and how willing they were to help me on my journey. A fellow scholar Richard Quigley and his wife Alex must also be thanked, it was such a wonderful opportunity to travel with like-minded people and of course have fun along the way, a friendship that is special.

And finally, to my wife Kim, her patience and support throughout this process has been simply amazing, we even managed to get married during the whole Nuffield experience, so thanks!

Abbreviations

BCI	Bank-less channel irrigation
CP	Centre pivot
EM	Electromagnetic
MDBA	Murray Darling Basin Authority
ML	Megalitre
ML/day	Megalitre per day
NSW	New South Wales
SDG	Sustainable Development Goals
USA	United States of America
WUE	Water use efficiency

Objectives

Identify and highlight the advantages and disadvantages of two different irrigation systems that have seen an increase in uptake and how to increase the performance of existing flood irrigation:

- Bank-less channel irrigation (BCI)
- Centre pivots (CP)
- Stubble retention on existing furrow irrigation

There is also a focus on soil that was previously viewed as difficult to irrigate, with personal experiences of installing these systems.

Irrigation in northern NSW is generally on vertosol soil types and this report focuses on irrigation systems that are suited to non-vertosol soil types – soils with a higher loam or sand content. In the irrigation industry these soils are colloquially known as red soils.

When considering new irrigation development, purchasing an irrigated asset, or developing existing fields to irrigation systems there are many factors to consider; soil characteristics, topography, water supply, crop requirements as well as a focus on economic factors including labour requirements, capital, and resource costs.

To do this, the report also focuses on:

- Soil characteristics and their impact on water infiltration
- Clearly defining BCI and CP irrigation systems
- System advantages and disadvantages
- Outline the cost of both systems to install
- Can we do better on previous systems before having to implement a new system

This report also provides a case study into 'PolyPipe,' which is an irrigation system that is widely adopted in the Delta irrigation areas within the USA.

Chapter 1: Introduction

Irrigation is defined by National Geographic (2023) as: "*To irrigate is to water crops by bringing in water from pipes, canals, sprinklers, or other man-made means, rather than relying on rainfall alone*".

Within the Australian landscape, irrigation land only accounts for 5% of tilled agriculture and less than 1% of total land mass. However, produces 30% of all agriculture production. Irrigation typically provides more than 90% of Australia's fruit, nuts, and grapes; more than 76% of vegetables; 100% of rice and more than 50% of dairy and sugar (NSW Irrigators' Council, 2023).

The irrigation sector makes a significant economic, cultural, and social contribution within the Australian agricultural and rural landscape, contributing to the United Nations Sustainable Development Goals (SDG) and in particular; Goal 2 (zero hunger), Goal 8 (decent work and economic growth), Goal 12 (responsible consumption and production), and Goal 13 (climate action) (United Nations, 2023).

Irrigators in Australia get the vast bulk of available water in the Murray Darling Basin (MDB). This is a system that stretches over one million square kilometres in the southeast of Australia. The recent east coast drought that peaked in 2019 saw a heighted level of threat to the systems' survival. This threat was not only in the form of the farmers ability to irrigate but bought heavy discussion with all parties involved in the MDB including those with political, environmental, cultural, social and agricultural interests.

Australian irrigators have a reputation of being leaders in WUE, however with a reduction in reliability across a number of irrigation valleys, such as the Namoi and Macquarie River basins, irrigation businesses have turned their strategic analysis even tighter on where their next irrigation move will be.

Irrigation is far more than the ability to increase crop production. It has a value attached to it that has seen dramatic capital increase post drought.

Table 2: Example of Macquarie Valley within MDB general security asset increase (WaterNSW, 2024)

	2017	2018	2019	2020	2021	2022	2023
Price $/ML	$1500	$1600	$1800	$2000	$3200	$3500	$4000

Table 3: Example of Macquarie Valley land price increase – Narromine. (Rabobank, 2015)

	2015	2023
Median $/ha	$1855	$6177

Table 2 and 3 highlight the need for farmers to understand the cost or value of the asset they are dealing with and when focusing on return from asset managed, how important it is to understand the system driving that return. Whilst BCI and CP irrigation techniques are not new systems, the author will aim to highlight how these two systems in particular can drive a greater return on red soils. The report highlights some of the key analysis involved when considering installation of BCI or CP irrigation systems on farm and why it is important to understand the characteristics of the soil before developing an irrigation system.

Chapter 2: The importance of understanding soil

Soil health is key to crop performance and ultimately profitability. It is vital that soil is understood before implementing an irrigation system as different forms of irrigation systems will impact soil infiltration levels.

Typically cotton production in the northern MDB is grown on vertosols; known as grey and brown cracking clays. These soils are suited to typical (but not limited to) furrow irrigation and row cropping. They have a higher percentage of clay particles throughout their soil profile and shrink and swell naturally, assisting with their own soil rejuvenation (Mckenzie, (Ed.), 1998). However not all irrigated land is of this nature, areas of loam and sandy soil mean that different management approaches and irrigation techniques need to be applied to deal with challenges such as seedling emergence, crusting or root extension can be restricted without good soil management as examples.

This report includes two case studies that are more suited to soils with a greater loam or sand content. Further known problems that are faced with these type of soils are:

- *they have slow water entry at the surface,(infiltration)*
- *hard setting in nature,*
- *crusting and/or flaking when the soil is dry* (Mckenzie, (Ed.), 1998).

These soil properties can make crop irrigation management difficult and unprofitable if the system delivers poor crop production. It can also provide real challenges to crop emergence, as the soil can set hard once wet, and seedlings will struggle to emerge out of the soil.

<u>*Soil Texture*</u> is the relative amount of sand, silt, clay, and organic matter in the soil (Armstrong, 2018). For example, a sandy loam has a greater amount of sand than other components, while a heavy clay is predominantly composed of clay particles. Figure 1 highlights the soil texture triangle.

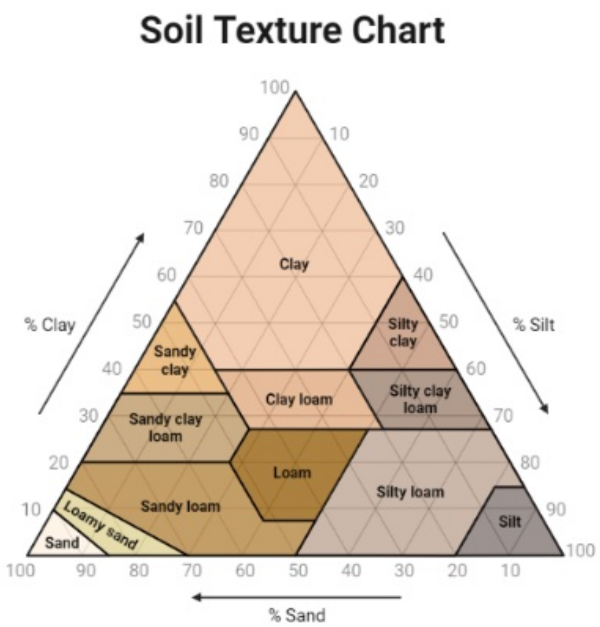

Figure 1: Soil triangle Diagram (Source: Groenendyk et al, 2015)

The soil diagram in Figure 1 clearly displays how different percentages of sand, silt and clay form different known soil types. Vertosols will fall in the top half of the triangle as they have a greater percentage of clay content, while this report will focus on the irrigation systems that can assist with sandy clay loams, loams, and sandy loams that are redder in nature.

Soil structure describes how the mineral particles and organic matter are arranged to form aggregates, as well as how pore spaces are arranged within and between aggregates. Soil with good structure will hold more water that's available for plant use than those with poor structure. (Armstrong, 2018)

Knowing how much water soil can hold makes irrigation planning easier and can improve WUE. Figure 2 highlights how different soil textures have different abilities to hold water. This term is known as soil water holding capacity. The water holding capacity of the soil will greatly influence irrigation management and timing of irrigation cycles throughout a crop seasons. Throughout different farm visits in both the United States and Australia, it was typical that irrigation cycles on soils with a higher loam and sand content were more frequent during peak water demand. Cotton production during summer would see these irrigation cycles occurring every 4-7 days, opposed to farmers irrigating vertosols soils every 7-10 days, which relates directly back to the soils water holding capacity.

Red soil has a reputation for being more challenging to grow cotton on then cracking clay soil, particularly during crop establishment. With the right irrigation system design and correct management of the soil, high yields and profitability are achievable and have been noted. Water can only infiltrate into the soil at a certain rate, and the longer the water is applied the slower this rate becomes. The rate the water can enter the soil is called the soil infiltration rate. This report focuses on two systems – one that is pressurised and one that is surface irrigation. Both irrigation types have different soil infiltration characteristics:

- With pressurised irrigation systems the rate at which water is applied must not exceed the soil's infiltration rate.
- With surface systems the application at any one point must be long enough to allow enough water to enter the soil profile (Armstrong, 2018).

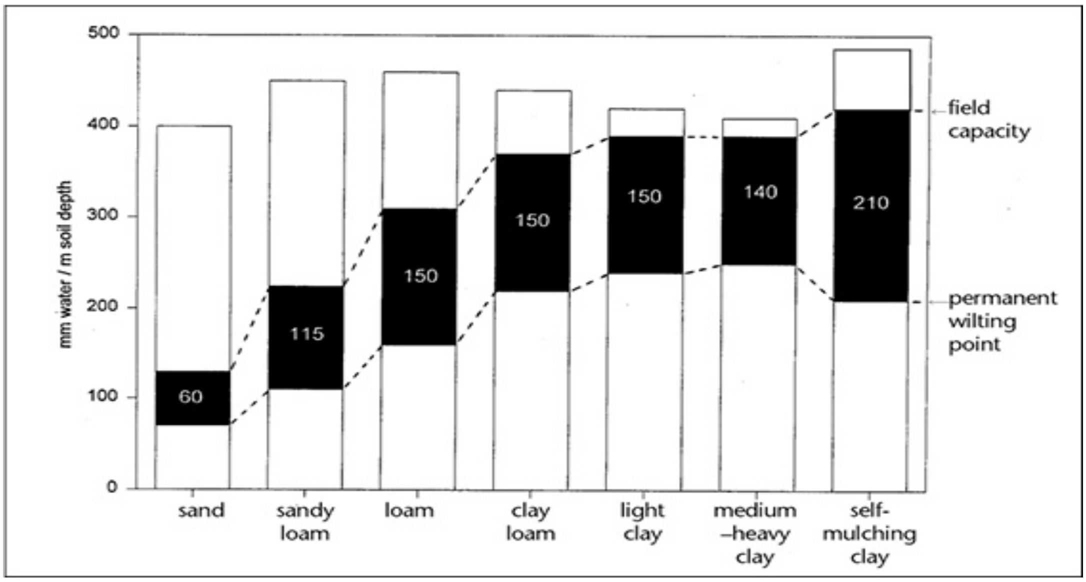

Figure 2: Water holding capacities of different soil types (Source: Cotching, B, 2011)

There are many other components to soil that that can influence the impact of irrigation. However, it is of the authors opinion that understanding soil texture, structure, infiltration rate and water holding capacity is a valid starting point for irrigation system design. Table 3 below displays the average infiltration rates for different soil types.

Table 3: Average infiltration rates for different soil types: (Source:Armstrong, 2018)

Texture group	Suggested application rate (mm/h)		Infiltration rate range (mm/h)
	Average soil structure	Well-structured soil	
Sands	50		20-250
Sandy loam	20	45	10-80
Loam	20	45	1-20
Clay loam	20	40	2-15
Light clay	2	5	0.3-5
Medium-heavy clay	0.5	5	0.1–8

Infiltration primarily depends on soil texture, structure, porosity and bulk density, but ground cover, slope and dispersion characteristics can also influence the soils infiltration rate. This highlights another challenge that irrigators face on red soil in furrow irrigation – the ability to sub the hill right through in appropriate time. This proves a significant challenge and can often involve increased labour and rebuilding rotor bucks to ensure both side of the plant line receive water. Figure 3 highlights how water is failing to infiltrate the soil on red soil.

The figure on the left displays the challenges of red soil, in an ideal world the dry furrow would be saturated as the irrigation has infiltrated the hill.

However in this scenario the water is struggling to infiltrate the hill, this will result in the plants having less access to water and also a small refill point. Thus there will be a shorter period between the next irrigation cycle.

Figure 3: Red Soil displaying poor water infiltration in season. (Source: author, Narromine, 2016)

There is a range of tools and techniques available to farmers to help understand their own soil. These include, but are not limited to, soil tests, backhoe pits, electromagnetic (EM) surveys and engaging with a soil scientist. These tools would be highly recommended before implementing a new irrigation system. Management techniques such as cover cropping, deep cultivation, soil amelioration and irrigation management can all influence the performance of the soil and influence the efficiency of the irrigation system. There is no golden solution but rather a combination of techniques and practices that will greatly control the outcome.

Figure 4 on the left further displays the difficulties farmers are facing during crop emergence, this particular image is on a red knob within a field, the plant line in the middle of the hill is struggling to get wet. This resulted in poor crop establishment which led to yield loss. This is part of the challenge that irrigators with this type of soil are trying to overcome.

Figure 4: Poor Soil Infiltration (subbing) during watering up. (Source: author, Narromine, 2021)

Chapter 3 will highlight two irrigation systems that are available to farmers who are typically trying to irrigate soils that have a greater sand or loam content and are trying to overcome the challenges presented, it is evident that understanding soil characteristics is extremely important.

Chapter 3: Irrigation system choice

3.1 Bank-less channel irrigation (BCI)

3.1.1. Defining BCI

BCI has been used in the MDB since the early 1990's, particularly on rice fields in southern NSW. Over the decades, as irrigators faced challenges on red soil, it has been modified and adopted to suit row-cropping in the northern MDB. There are discrepancies between BCI designs and each design can be slightly different. When designing a BCI system, the author recommends engaging with a water consultant on the type of BCI system that will be suited.

BCI offers an alternative method of surface irrigation. The basic concept is that water is delivered to terraced bays via a side delivery channel that is bank less in nature, or below the ground. The supply channel runs with the slope of the terrain and met with a check or control bank. These checks control the flow from one bay to the next. The terraces generally have a step of 7cm to 30cm and within the terraced bays there is zero side fall or grade (Figure 4).

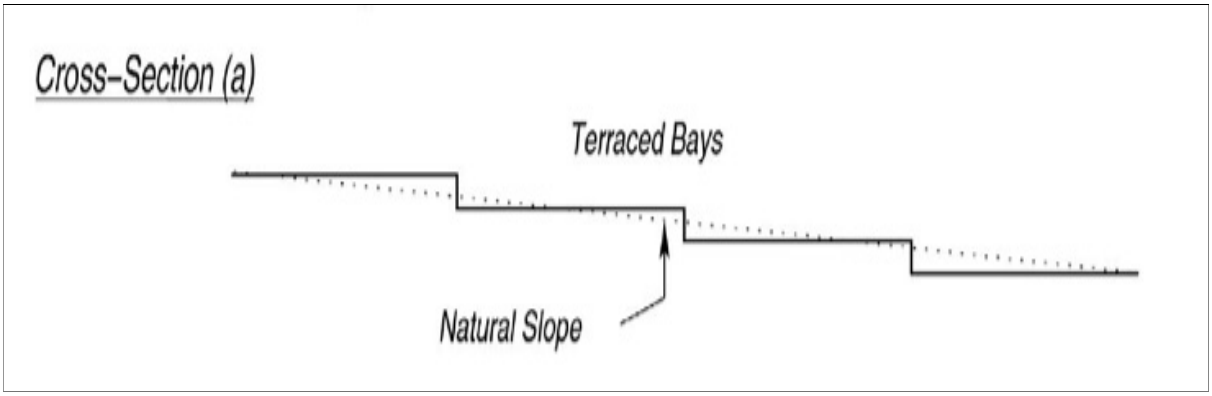

Figure 5: Cross section of a BCI Layout (Source: CottonInfo, 2014).

Typically, BCI design with row cropping has included a down slope within the terraced bay that still results in a tail drain at the end of the field, as shown in Figure 5. However there has been an increase in designs on typical red soil with a zero grade. The zero grade within the terraced bay means water enters and exits from the same bank less channel. The theory being here that water can be held on the bay for an extended period of time to help with increased infiltration. The minimum step between terraced bays must be 7cm to allow enough head pressure for the water to drop down to the next bay once the outlet is opened.

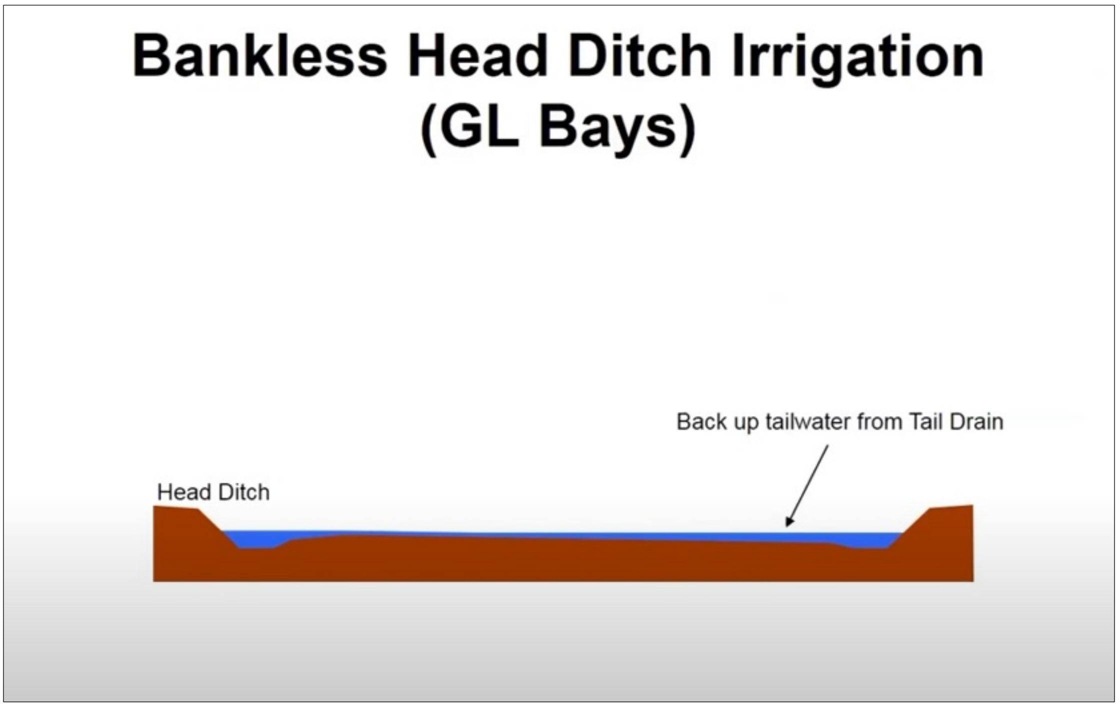

Figure 6: cross section of a Glenn Lyons BCI design (Source: Cotton Australia, 2021).

The zero-side fall and zero grade in each bay allows for greater irrigating consistency before water is moved to next bay via the control check. Figure 7 displays an aerial view of a BCI system. Figure 8 displays a typical check bank with a check or structure that stops the water from entering the next bays. There are endless forms of different stops available for farmers with different cost and application purposes.

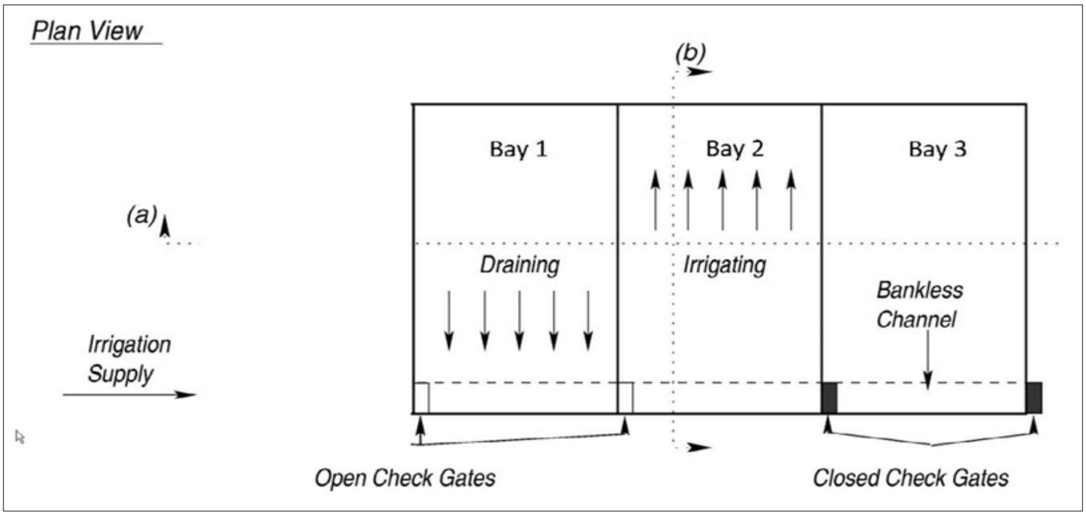

Figure 7: Aerial View (Source: CottonInfo, 2014).

Figure 8: Bank-less check for controlling flow of water between bays (Source: author, Griffith, NSW 2020).

When designing BCI, the process starts with the capacity of water supplied. The amount of megalitres (ML) per day will determine bay sizes and structures required. It is imperative that structure and bay size is matched to flowrate (ML/day). The smaller the flowrate the smaller bay design which is needed. This will ultimately increase the cost as more structures will be required per hectare.

The zero-side fall and zero slope designed terraced bays are the focus as it allows the farmer to overcome traditional challenges with irrigating sloped red soils.

3.1.2 Advantages and disadvantages

Now that BCI has been defined and understood, a summary of the advantages and disadvantages of the system is shown below in Table 4.

Table 4: Advantages and Disadvantage Snapshot for zero grade BCI

Advantages	Disadvantages
• Increase infiltration	• Cost of shifting dirt for zero grade
• Labour saving – irrigation is 10% of siphon labour requirement	• Structure and installation cost
• Tail water management – minimal tail water if managed correctly	• Only suited to certain soil types – not suited to heavy clays
• No Siphons or rotor bucks required	• Reduced area – the banks between bays typically reduce irrigated area by 2%
• Machine efficiency	• Wet harvest conditions
• Increased cropping options, ability to water a range of crops quickly and easily	• Design is imperative to performance
• Ability to hold storm water run-off in fields, if required	• Bay maintenance

There is much debate regarding the advantages and disadvantages of different systems, but Table 4 above aims to provide a snapshot for the zero-grade designed BCI, with the clear objective of answering why this system is suited to the soil in focus.

By having zero-grade and zero side fall within a bay, the water can be pooled on the bay for a length of time. The bay is then acting as a 'bathtub' and thus water cannot run off the field but instead is it forced to infiltrate the soil. This is supported by farmers sentiment across the MDB and further supported by soil probes used throughout the season. Once the water has infiltrated the soil, the 'bathtub plug' (check) is then pulled and the next bay or bathtub is filled up. BCI allows easy manipulation of the timing of irrigation on each bay and can further influence the infiltration rate of the soil. When irrigating, the farmer can literally hold the water on the bay until the desired infiltration is met. They can also control the speed of which a bay is watered by different heights at the control checks.

BCI allows farmers to ensure the challenges of water infiltration (subbing) is overcome and that beds can be watered right to the top as the design allows them to pool the water until desired infiltration has occurred.

If managed correctly, there is minimal tail water run-off in a BCI system. This essentially reduces further labour and diesel/electricity costs. Typically, the last bay in a system layout is 40 percent of the area of the bay above it and thus the water that runs off the 2nd last bay above it will be enough to irrigate the last bay. Once the last bay is full, it is generally enough water to infiltrate the soil to the required point and minimises water leaving the system.

Reduced labour savings and machine efficiencies are a great advantage that BCI offers. The required labour during the season for BCI is only dropping or opening the gate at each bay when the bay has finished irrigating, an easy process that requires minimal time. BCI does however require more observation throughout the season not to overtop beds or furrows.

Automated technology is increasingly available for farmers to implement in BCI systems, further increasing labour efficiency. Machine efficiencies are gained as there are no head-ditch channel and rotor bucks, allowing machines to turn quicker when in-crop operations occur. This means crop applications can be made in a timelier operation.

No syphons and rotor bucks also allow the alternative crops to be watered quickly and easily if needed. When surface furrow irrigation occurs via a head ditch and syphons, rotor bucks are required to assist with the direction of water travel, a task which takes time and machine use. BCI takes this away from the system as once it is installed, crops are available to be irrigated all season.

Whilst the zero-grade design BCI advantages are clear for infiltration purposes, there are challenges in extremely wet conditions, particularly around harvest. When a bay has zero-grade it is only suited to well-drained soil types or soil texture with a higher sand and loam content. There are negative experiences from farmers who have installed zero-grade BCI system on heavy clays, including delayed picking and harvest.

Zero-grade BCI has also been used to control periods of intense storm run-off. The bays can pool water until existing tail water return systems have been able to handle storm run off, the checks can then be operated to reduce the speed and volume of which the storm water will run off the fields.

Disadvantages such as the cost of structures, moving dirt and maintenance of a BCI system will be explored further in section 3.1.3 below. A range of advantages have been explained in helping identify an irrigation system that is suitable to implementing on soil that is typically a challenge to irrigate.

3.1.3 Cost of BCI

As with most irrigation systems, the cost of implementing a system can be a financially burdensome. However, the larger area developed generally brings the cost per hectare down. It is vital to get the setup right from the initial design process right through to implementation of structures. Engaging with a design consultant to clearly identify the cost of implementing BCI is a necessity.

There are two main costs to consider when researching BCI:

- amount of soil to be shifted; and
- cost of structures.

Dirt will be required to be shifted using professional earth movers, the volume largely dependent on BCI design, existing slope and side fall and the capacity of the system being built. While a clear cost can be calculated on the movement of dirt, there are some costs that cannot be quantified simply by the amount cubic meters. These 'hidden costs' include:

- **The changing of soil structure/type from cutting or filling the terraced bays.**
    - Often after a BCI earthmoving process, farmers will notice areas of fields that have changed their performance for the better or worse as a result of the soil change. For example, if a cut of 20cm has occurred, the removal of organic matter and nutrients that is typically found in the topsoil profile is now gone.

- **Temporary topsoil removal**
    - Topsoiling is a process carried out by earthmovers when developing a field. It involves removal of the topsoil (generally the top 5cm), stockpiling it, then carrying out the design. The topsoil is then returned to the field and spread evenly over the heavy cut areas, thereby taking less time for the soil to rejuvenate. However, this will clearly increase the cost of implementation as it requires an increased amount of dirt to be moved.

- **Use of soil ameliorants for soil health**
    - Soil ameliorants increase soil health and help amend poor soil infiltration that may arise from heavy cut areas. These are inorganic and organic chemical soil conditioning products applied to enhance the quality of soil and therefore improve plant health, growth, and revegetation. Examples include gypsum, lime, chicken manure or other sourced materials. Farmers should research and understand soil rejuvenation requirements before introducing a soil amelioration program, as well as also understanding the soils properties. For example, a gypsum program might be recommended. However, if the soil texture is less than 30 percent clay, then gypsum will potentially have limited impact on helping with the soils infiltration rate.

A quality earthmover is required when implementing zero-grade BCI as the final brush of the bays allows for consistency when irrigating. If bays are left with hollows and rises this will result in non-uniform crop growth and create an area of pooling that will create waterlogging.

The cost of structures within a BCI system is often overlooked. There are a range of options and products available for structure choice between bays and often decisions are made based on personal choice or existing supplier relationships. 'Padman Stops' located in NSW is one example of a business that provides a range of structure solutions for different BCI systems. A typical BCI system structure and cost is identified in Figure 5 below.

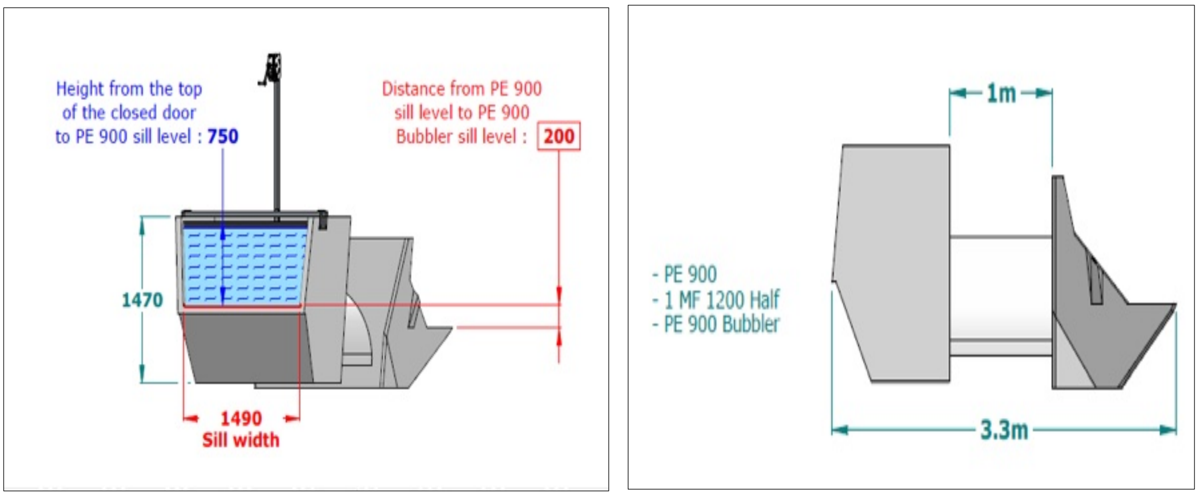

Figure 9: PE900 with Bubbler (Source: Padman Stops, 2024)

The cost and time to install these structures needs to be factored in, as well on irrigation system choice. Figure 6 below displays an alternative bay stop that may be used in BCI.

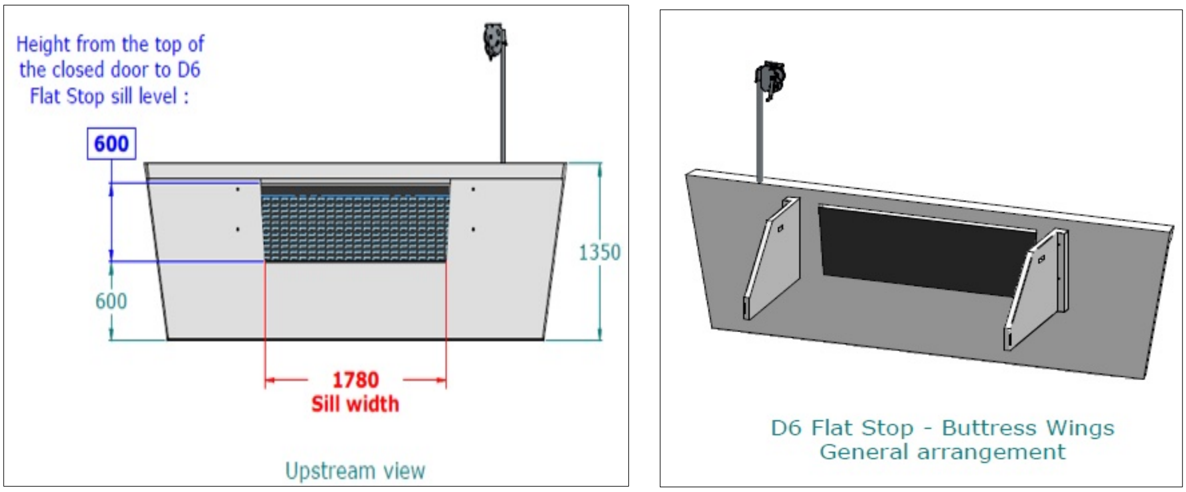

Figure 10: Padman Stops D6 Solution (Source: Padman Stops, 2024)

BCI also has an ongoing maintenance cost to ensure the system operates efficiently. Ideally, bays should be relevelled every five years – subject to climatic conditions – but there is a cost attached to this. Maintenance of banks between bays can also prove difficult, but an increased use of chemical residuals available in different cropping systems is making this job easier

3.1.4 Site example

The author has created Table 5 to highlight the cost of implementing a zero-grade BCI system. This cannot be applied to every individual scenario and the amount of dirt to be shifted, as well as structure choice, will great greatly influence the final outcome. It simply provides a guide.

Table 5: 50ha Bank less site costing example (Source: author)

Site Activity	Quantity	$/activity	$ Total	$/ha
Field Surveyed	1	$450	$500	$10
Field Design	1	$2,000	$2,000	$40
Earth Moving Bulking	Approx. 450 cubic meter/hectare	$3/cube	$67,500	$1,350
Earth Moving Topsoiling	20% of the area	$3/cube	$13,500	$270
Structure Choice	8 (PE 900 with Bubbler)	$4,200	$33,600	$672
Installation of Structures	8	$600	$4,800	$96
Total Cost			$121,900	$2438.00/ha

Assumptions have been made in the calculations above and this does not include fuel cost of the development or ongoing maintenance of bays. The approximate figure of $2,500/ha for cost of developing a BCI system is only an approximate but could be adopted in the pre-planning phase. The amount of cubic meters of earth moved and choice of structures will have the greatest influence on the final figure. It is important that an economic analysis is calculate on each individual site before implementing.

In summary, this section of the report has provided insights into the BCI system option when dealing with non-vertosol soil types, which has been implemented widely throughout the MDB system.

Figure 11: Bankless irrigation in the Northern MDB during crop emergence (Source: author, Narromine 2019)

3.2 Centre Pivot (CP) irrigation system

3.2.1 Defining CP irrigation systems

Centre Pivots (CP) provide an alternative irrigation system, especially if the slope/terrain of the field does not suit surface irrigation. CPs are common across all irrigation districts and have been used since the 1960's (NSW irrigators' Council, 2023). The two leading factors driving the adoption of CP irrigation systems have been labour savings and water savings (Smith et al., 2014). In the cotton industry, the average water applied by CP systems since 2011-12 was 30% less than that applied using furrow irrigation, whilst maintaining similar yields and the median labour requirement compared to furrow irrigation reported for CP's was 25% less (Smith et al., 2014).

CP irrigation systems also deal with soil variability and provide an option for farmers to irrigate land they typically would have not irrigated using surface irrigation. Since 2001, there has been an increase in lighter soils on which CP systems are used, in particular more sandy loam and sandy soils (Smith et al., 2014). CP systems offer an alternative method of water application that can be suited to these lighter soils through manipulation of the infiltration rate. Irrigation can also be applied more accurately, particularly where challenges with crop emergence and hard setting soils would have proved difficult in the past.

CPs are a well-known, common overhead irrigation method where water is supplied via pressurised supply line. They have a fixed centre tower containing a water supply point and power source around which the other spans and towers rotate. Figure 12 display a basic overview of a CP system and the author will focus on why these systems are suited to irrigating non-vertosol soils.

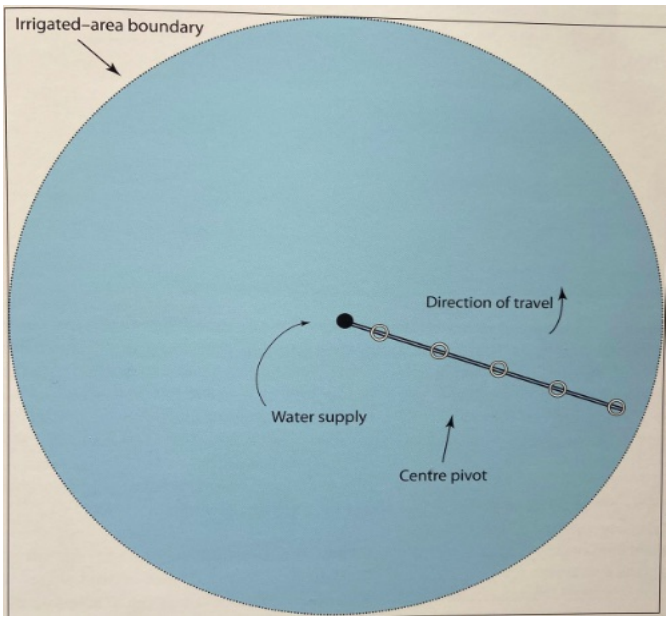

Figure 12: Centre Pivot overview (Source: Smith et al, 2014)

3.2.2. Advantages and disadvantages

CPs are common but still provides challenges, as seen during this international study travel. Most of those interviewed confirmed that with a regular maintenance schedule and greater understanding of their system performance, challenges could be overcome. Table 6 highlights some of the advantages and disadvantages of the CP system, as outlined by those farmers interviewed.

Table 6: Centre Pivot Advantages and Disadvantages

Advantages	Disadvantages
• Ability to irrigate undulating country	• Upfront capital cost for development
• Labor savings	• Maintenance and system performance
• Water application saving	• Machine breakdowns during critical periods
• Ability to double crop	• Circle paddocks
• Supplementary irrigation	• Pressurised system leads to higher pumping cost
• Minimal earthworks required and minimal earthwork maintenance	• Higher running costs in fuel and electricity
• Maximise value from small rainfall events	

A range of crops are grown under CPs throughout the MDB, and they allow flexibility to rotate crops or irrigate a desired crop of choice. Providing the system capacity of the CP is designed to meet the crops peak water demand. It can be argued that there is no crop type that is not suited to overhead irrigation. The ability to have flexibility in crop choice is a great advantage of CP systems.

Irrigating sloped or undulating country also allows production of an area that previously may not have been an option. It is stated by the NSW Department of Primary Industries (irrigation system and pump selection) that a CP system can deal with slops of up to 20 percent. This is verified by the authors personal experience - when dealing with slopes greater than 5%, additional management such as increased crop cover or variable rate irrigation is needed to ensure run off is minimised.

Similar to the BCI system, labour saving and machine efficiency is also experienced when implementing CP systems. No syphons and rotor bucks are required in the CP system, and machines have good operating efficiency. Automation is more widely adopted then that of the BCI and many CPs are now operated from mobile phone or desktop computers with its performance monitored remotely. This has offered labour efficiencies for staff to complete other tasks. The system can also be setup so notifications are received when the CP experiences issues, such as stopping or when pressure drops below the desired rate.

The ‘dead area’ around the circle of a pivot can be a disadvantage as it is often unproductive and there is a cost to controlling weeds in the fallow period. There are options for walkable end towers that swing out and water these areas, however when viewing these there were not to many positives. This technology needs to be explored further.

‘Bogging’ or ‘tracking’ issues are another disadvantage of CP systems, which is less of a concern on lighter soils. Farmers have adopted different management techniques such as wheel track renovators, spreader bars around towers and half sprinkler plates to overcome bogging and tracking.

Other disadvantages include the upfront capital cost, higher pumping cost and system performance.

Returning to the main objective of this report, to irrigate non-vertosol soils, CPs are excellent in dealing with crop emergence and when system management is matched with the soil infiltration to ensure minimal runoff is experienced, high yields can be achieved. They do really provide a solution to irrigating non vertosol soils.

In Figure 13, a pivot can be seen in the background, this farmer was utilising overhead irrigation on undulating country, they were also using retained stubble to assist with soil infiltration and reducing runoff. While maintaining the soil structure through minimal soil disturbance, excellent practice.

Figure 13: Cotton Emerging under a pivot with the use of stubble (Source: Author, Boggabri, 2022)

3.2.3 Cost of CPs

System capacity is critical. It needs to be high enough to satisfy peak crop demand and the irrigation management, while minimising capital and operating costs. This ultimately comes down to system design when installing or implementing CPs and it is recommended to engage in a professional for advice. It is also important to understand the ongoing energy cost of the machine that may not be calculated in the initial capital cost of the machine.

When focusing on the cost of a CP system, there are three major components a farmer needs to consider:

- Centre pivot.
- Pump station.
- Water supply line.

Many irrigation dealerships supply CPs and it is not the aim of this report to analyse the different brands. Farmers should conduct their own research into different brands, materials used and dealer backup service before deciding. Some elements for consideration include tyre size, span material, sprinkler packages and control box options. These items will be a small percentage price change on the overall cost.

The pump station of the CP is a significant cost of the system and it will ultimately determine the system capacity or be matched to area wanting to irrigate under a CP. The rate at which water can be supplied to the area under CP is referred to as the system capacity and is expressed in millimetres per day (mm/day). It is the main criterion that the pump, pipes and sprinkler design is based on.

The supply line is the third main cost of implementing a CP system. This will be a PVC pipeline that will run from the water source (pumping station) underground to the centre tower of the pivot. The deeper this pipe can be laid the greater safety the pipe will have from tillage operations or shallow excavations. It is also recommended that once the pipeline has been laid, imagery or GPS guidance be used to clearly record the location of the pipe for future earthworks/developments.

When deciding and calculating pipeline size, it is important to factor in friction loss. The higher friction required to deliver the correct amount of water will result in an increase of energy, this will result in higher pumping costs. Consult with the dealer and make sure they analyse the different friction loss scenarios that may occur with the choice of different pipe diameters. While a larger pipe choice upfront might result in an increased upfront cost, over the lifetime of the machine it may reduce the pumping cost significantly.

Factor in all the costs associated with a CP system and generally it will require a large initial capital investment. It is expected that this type of system should have a 20-plus year lifespan before upgrades or modifications are required.

3.2.4 Site example

Like the BCI system, this example is site specific. Cost will change depending on system capacities, machines chosen and sprinkler package. It has been provided to display an overview of cost of implementing a CP system. The upfront capital cost is significant in a CP system, but with the potential of reducing water use per bale or tonne of grain, and by overcoming the challenges of irrigating on non-vertosol soils, they do provide a solution.

Table 7: 50ha Pivot site costing table (Source: Author)

Activity	$	$/ha
Pivot Machine	$250,000	5000
Mainline Supplied and Installed	$60,000	1200
Pump Station	$20,000	400
Generator to run CP	$20,000	400
	$350,000	$7000/ha

In summary, while the two systems will provide alternative irrigation options for non-vertosol soil types, it is imperative that the investment decision is evaluated thoroughly. Both return on investment and payback period is two financial metrics that can be used. Not all the advantages of the systems are easy to quantify, such as improved lifestyle from reduced labour savings.

3.3 Case Study: Poly Pipe Flume - Delta Mississippi Region, USA

The Delta region of Mississippi and Arkansas states in the USA were visited as part of the research. This region is highly productive on an alluvial floodplain with access to alluvial water at approximately 20 metres below the surface. The region is known for irrigating cotton, corn, soybeans, rice, and peanuts.

In this region, 90 percent of irrigation occurs from groundwater and of that, over 80 percent of the area is using the irrigation technique of 'polypipe flume'. The recyclable lay-flat polyethylene tubing (hereafter referred to as 'polypipe') has been the underlying reason why the region has trended towards furrow irrigation. Figure 14 highlights the 'polypipe' connected directly in a bore and laid towards the field of choice to irrigate.

Figure 14: Polypipe connected directly to a bore (Source; author, Mer Rouge, Louisiana , USA, 2023)

Polypipe became attractive for the irrigators of the region as they discovered it could be setup and removed mechanically (Figure 15), could be trafficable during the season, and can be set up without the need for a head-ditch still in a uniform manner that is suited to row-cropping or furrow irrigation.

When visiting and interviewing Mr Allen Spiers in the town of Mer Rouge, Louisiana USA, he provided great insight into the product and he highlighted how it is '*cheap, simple and an effective way of getting water from A to B.*' The product offers a cost-effective way to furrow irrigate using groundwater directly from the bore. The product can be used on flows of 1.2 mgs/day up to 15 megs/day. The product has a low flow ability and once the water has been lifted out of the ground, it relies on relatively low pressure to deliver it to the field.

Figure 15 : Mechanical installation of Polypipe (Source: author, Mer Rouge, Louisiana , USA, 2023)

The polypipe is manufactured by Delta Plastics Pty Ltd, comes in rolls of 400m length and cost of USD $350 per roll. The plastic itself can easily be handled, cut to length, and stored for future use. It is ideal for single season use, but there was some farmers in the Delta attempting to get more than one season use from it. Currently, at the end of the season Delta Plastics arrange pick-up of the material and the product is recycled. Anecdotally, the system seems easy to use and the company providing the system offers an app software program that calculates the size of the flume and size of holes required for the area watered.

Figure 16: Further examples of the low cost irrigation system. (Source: author, Mer Rouge, Louisiana , USA, 2023)

In summary, further research could be beneficial to understanding how this product works, especially in Australian conditions. It could be a suitable option to explore that would provide some solutions to the challenges of irrigating red soils in the MDB.

3.4 Improving existing flood irrigation

Whilst BCI and CP offer a solution to overcoming the challenges of irrigating on non-versotol soils, it is clear there is a cost the grower to install these irrigation systems. There has been a recent rejuvenation of growers working together and collaborating with their RDC's to also enhance their existing flood irrigation fields to enhance their yields and ultimately increase their profitability.

The financial cost of Installing BCI or CP is the initial barrier to entry, which raises the question how can we get better performance out of our existing flood irrigation, the author collaborated with fellow irrigators in the Macquarie Valley and it was evident that in general the majority of irrigators feel we can improve existing flood irrigation without the need for capital expense in the other systems.

Again, the biggest challenges being faced by growers was that generally the soils sealed up during the season, emergence was often a challenge with infiltration to the seed proving difficult and increased irrigations during the season as the water holding capacity of these soil types became limited.

The author attended a 'Red Soils Focus Group' held by the local Macquarie Cotton Growers Association, there was a clear direction following the meeting that if the logistical challenges of retaining some form of cover crop within the furrows can been achieved, then some of the challenges can be overcome. Different cover crops will result in different outcomes, this is not the purpose of this report, rather that some form of cover cropping will result in increased water infiltration and greater soil structure.

Figure 17 below highlights what was being achieved under overhead sprinkler irrigation on red soils, an established cover crop providing many benefits to an emerging cotton crop. The challenge is trying to implement this is a furrow irrigation system.

The challenge around implementing this system in a furrow irrigation system is really around machine operations and operational logistics.

Also around cover crop establishment. Under a CP system a cover crop can be established with relative ease as the minimal amount of water can be applied via the sprinklers to assist with emergence. In comparison to the furrow irrigation, it would require substantial watering if rainfall was minimal to establish the cover crop.

This would also have to be done at the start of the cover crop season, thus making the furrow field un-trafficable for a period of time, and potentially using a substantial amount of water.

Figure 17: Cover Cropping under a Centre Pivot System (Source: author, USA – Texas, Clarendon 2023)

That being said, this potentially could be worth the investment if it results in reduced water usage within the cotton season and overall system benefits.

The Author and other members of the ‘Red Soil Focus Group’ believed it was worth implementing on part of their existing flood irrigation. The author will share his experience below.

Figure 18 below displays a wheat cover crop that is emerging in April. This particular cover crop was spread at a rate of 50kg/ha and then mechanically incorporated in front a rain event.

Figure 18: Cover Crop Emerging on existing furrow irrigation (Source: author, Narromine 2023)

The cover crop is then grown out to a certain point in time, it is understood that this point is just before head emergence within a wheat crop. The idea being that there is enough lignan within the wheat plant to provide it with strength to withstand the watering applications. By waiting till this point for termination of the cover crop, it also means the plant has done plenty of work under the ground that the root system will be assisting with soil structure and the infiltration of the soil network.

Figure 19: Cover crop on Furrow irrigation just before Termination (Source: author)

Figure 19 above, highlights the stage of the wheat cover crop just before head emergence, this crop will now be terminated and sit there until cotton planting and irrigation starts around the middle of October. It must be noted that one of the challenges of having a suitable seed bed may need to be overcome, that's because the cover crop may potentially impede on the planters ability to traffic correctly. This was also raised at the red soils workshop and is one of the logistical challenges.

It is clear from the authors own experiences and especially by those who attended the 'Red Soil Focus Group' that there is a desire to enhance existing irrigation performance on non-vertosol soils. It will be great to explore the yield outcomes and measurable results from these type of trials and research collaboration going forward.

Conclusions

This report has identified two irrigation systems that offer a solution to overcoming the challenges of irrigating non-vertosol soils – namely the bank-less channel irrigation (BCI) system, and the centre pivot (CP) irrigation system – and both have been explored as part of this research.

Challenges of irrigating non-vertosol soil include plant emergence, crusting, hard setting soil and slow infiltration rate, and can be better managed with capital investment into BCI and CP systems.

It has become clear that understanding the soil type, texture and infiltration rate is the first step to implementing a new irrigation system. No system is inherently better than another; each individual irrigation system should be selected and designed depending on a range of factors specific to each field site. The most appropriate irrigation for a particular situation should consider the topography, soils, crop water requirements, energy, labour, and irrigation performance.

This report has provided an insight into the importance of understanding soil, as well as the cost of implementing the two irrigation systems. It has aimed to provide insights into factors that can influence final choice of irrigation. It also highlights how these systems can help overcome the challenges of trying to irrigate soils with a higher sand or loam content then traditional vertosol soils, that are irrigated in the northern MDB.

The author also concludes that common syphon surface irrigation is the most common system due to the low capital cost and low energy requirements and is still being widely installed today. Well designed and managed syphon surface irrigation can achieve application efficiencies and highly productive systems. With a change in practice and increased stubble retention on furrow irrigation, there is potential that existing furrow irrigation will still be able to provide a sound return on investment.

Optimised irrigation involves maximising the systems irrigation WUE. As identified, no system is perfect, but by optimising whichever system is installed, the productivity per megalitre can be improved. Efficiency comes from design and management and is not an inherent characteristic of the system itself.

Recommendations

- Engage with a professional consultant before considering and installing a new irrigation system on farm.
- Take time to visit different set-ups and designs. The irrigation industry is well-established, and many farmers are willing to share what has worked (and not worked) for them.
- Soil health is key to crop performance and profitability, and it is vital that soil type is understood before implementing an irrigation system, especially during the peak season.
- Irrigation system design can dramatically influence the efficiency of water applied to the field and thus have a direct relationship to cost per megalitre applied.
- If irrigating on non-vertosol soils with poor results, bank-less channel and centre pivot irrigation systems are worth investigating as an option to overcome the challenges faced.
- Ongoing industry research and development, as well as regionally based on-farm research producing tangible results is critical.
- Irrigation still offers a sound financial return on investment, however it needs to be calculated carefully.

References

Armstrong, D, (2018), “Soil texture and infiltration: Assessing your Soil Resources for Irrigation”, David Armstrong Agricultural Services, Bill Cotching and Colin Bastick, DPIWE https://www.publish.csiro.au/ebook/chapter/9780643103283_Chapter_8

Cotching, B, (2011), “Soil Water – Tasmania”, Soil Quality Website, University of Tasmania, https://www.soilquality.org.au/factsheets/soil-water-tasmania

CottonInfo, (2014), “Bankless channels; The Cook family case study”, Cotton Info Website, https://www.cottoninfo.com.au/sites/default/files/documents/CottonInfo%20bankless%20channels%20case%20study%20-%20March%202014.pdf

Groenendyk, D.G, Ferre, T.P, Thorp, K.R, & Rice, A.K, (2015), “Hydrologic-Process-Based Soil Texture Classifications for Improved Visualization of Lanscape Function”, PloS one, 10(6), https://doi.org/10.1371/journal.pone.0131299

McKenzie, D.C, (Ed.), (1998), “SoilPak: third edition”, Cotton CRC Internet Website, https://cottoninfo.com.au/sites/default/files/documents/SOILpak.pdf

NSW Irrigators’ Council, (2023) “Murry Darling Pasin Plan”,NSW, Irrigators Council website, https://www.nswic.org.au/murray-darling-basin-plan/

National Geographic, (2023), “Irrigation”, Encyclopaedic Entry, National Geographic Education Website, https://education.nationalgeographic.org/resource/irrigation/

Padman Stops, 2024, “Padman Stops Website”, Padman Stops website, https://www.padmanstops.com.au/

Rabobank, (2015), “Australian Farmland Values Report 2015”, 2015 Report

Smith, P, Foley, J, Priest, S, Bray, S, Motgomery, J, Wigginton, D, Schultz, J, Van Niekerk, R, (2014), “A Review of Centre Pivot and Lateral Move Irrigation Installations in the Australian Cotton Industry”, NSW Department of Primary Industries, https://www.cottoninfo.com.au/sites/default/files/documents/Centre%20Pivot%20Lateral%20Move%20Report.pdf

United Nations, (2023), “The 17 Goals”, Department of Economic & Social Affairs, United Nations Website, https://sdgs.un.org/goals

Water NSW, (2024), “NSW water Register”, Water NSW website, https://waterregister.waternsw.com.au/water-register-frame

Visits in United States & Australia

USA. Memphis Tennessee	Louis Dreyfus Company Adams Cotton Gin USDA Classing House
USA Louisiana Mer Rouge Monroe	Allan Spirers Jake Perry Maclendon Sharp Double M Farms
USA – Colorada, Denver, Hugo	Kalcevic Farms Poss Farms High Plains Harvesting
USA – Texas, Clarendon Panhandle Lubbock	Walker McAnear Lance Williams Dan Taylor – Busters Gin

Northern Territory and Western Australia	Bruce Connelly, Tipprary Station Douglas Daly Research Farm Sam McBean Brendan Griffiths Russel Keeley, Trevor Bass and Nick Bass Matt Stott, Steve Buster KAI, Jim Engelke and Luke McKay Petter Cottle CGS Jason Learch Matt Gray Fritz Bolten